TEST OF A ROTARY TRANSFORMER FOR DIRECT CURRENT

BY
P. L. BRADFORD
J. H. FLETCHER

ARMOUR INSTITUTE OF TECHNOLOGY

1911

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Construction and test of a
rotary transformer for

CONSTRUCTION AND TEST
# of a
ROTARY TRANSFORMER
for
DIRECT CURRENT.

A THESIS

PRESENTED BY

P.L.BRADFORD &

J.H.FLETCHER,

TO THE

PRESIDENT AND FACULTY

OF

ARMOUR INSTITUTE OF TECHNOLOGY

FOR THE DEGREE OF

BACHELOR OF SCIENCE IN ELECTRICAL ENGINEERING

HAVING COMPLETED THE PRESCRIBED COURSE OF STUDY IN

ELECTRICAL ENGINEERING

May 25, 1911.

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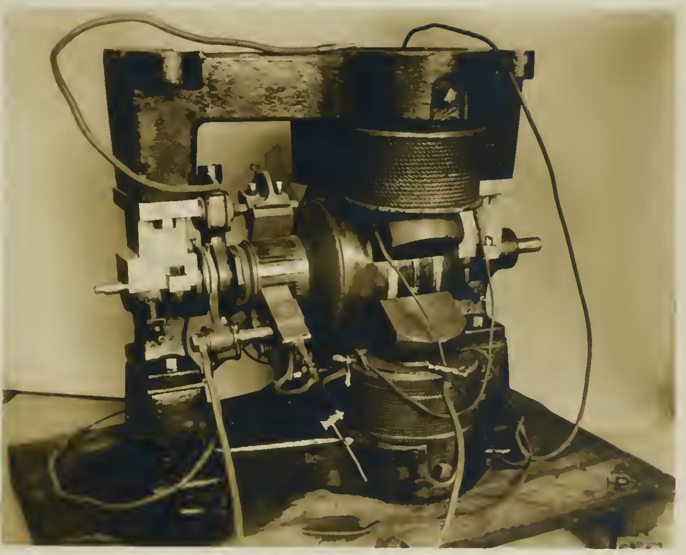

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CONSTRUCTION AND TEST
# of a
ROTARY TRANSFORMER
for
DIRECT CURRENT

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The introduction of Tantalum filament lamps in 1906 gave a great impetus to the lamp industry. The Tantalum filament changes its physical structure during use, losing its smooth, uniform surface, and becoming rough, off set, and brittle. This change takes place more rapidly on alternating than on direct current circuits. About two years later, the lighting industry received another advance in the shape of the Tungsten filament lamp. This lamp at 1.25 watts per candle power means a lamp over 200 times as good as a standard carbon lamp, each with normal life. Tungsten lamps of 6 to 20 volts have short, thick filaments and are very long lived and satisfactory. The low, specific resistence of the Tungsten gives the filament a very desirable dimensions, this advantage has caused a large increase in the use of low voltage lamps for many purposes, especially for residence lighting systems of from 27 to 60 volts. The low voltage lamps having a heavier filament for the same candle power, are more durable than the lighter filament of the standard voltage lamp. The longer life of this filament

is due to the greater diameter and shorter length, for the thicker filament is less effected by minute imperfections, and has proportionately less chance of containing such imperfections.

The object of the Rotary Transformer for direct current work is to combine in one highly efficient machine, the advantages of low voltage systems, motor-generator sets, and dynamotor sets, at low cost, low weight, small floor space, and simplicity. It must meet the requirements for the lighting of Shops, Hotels, Theatres, and Concert Halls, with metal filament or arc lamps. Rotary Transformers are adapted for balancers on three-wire systems, storage battery charging and multiple unit train control.

Up to the present time there has been advanced two theories for accomplishing this with the use of one commutator and one rotating member. These have been advanced by the General Electric Company of America, and Crompton & Co., Ltd., of London, England.

The General Electric method comprises a plurality of field poles, a corresponding plurality of brushes disposed about a commutator. The respective disposition of said poles about the armature is such as to form two magnetic circuits as given in the accompanying diagram, (Fig. I.), of the Stow Motor. The shunt fields are arranged to form two parallel circuits, each containing its regulating rheostat. For the purpose of safety to the machine, these rheostats are arranged so that when one is cut out the other is cut entirely in, they being so constructed that the position of one cannot be changed without producing a correspondingly opposite change in the position of the other. The motor and generator field poles are placed diametrically opposite to prevent the magnetic drag. The brushes of the motor bear upon the commutator diametrically opposite, supplying power to the rotating member. The generator brushes are placed diametrically upon the same commutator; their position may or may not be fixed with respect to the motor brushes. The load is connected between these two brushes. The change of potential on the load

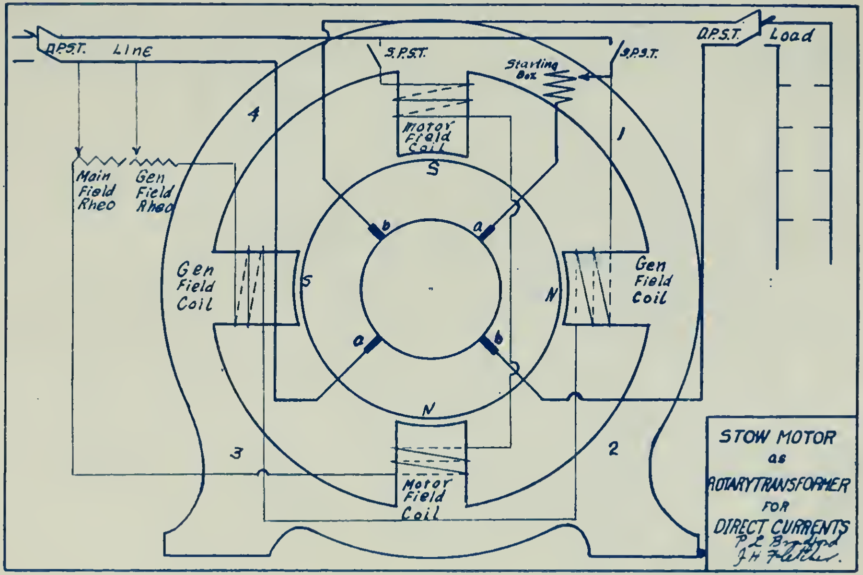

D.P.S.T.
Line
S.P.S.T.
S.P.S.T.
Starting Box
D.P.S.T.
Load
Motor Field Coil
Main Field Rheo
Gen Field Rheo
4
1
S
b
a
Gen Field Coil
S
N
Gen Field Coil
a
b
N
3
2
Motor Field Coil
STOW MOTOR
as
ROTARYTRANSFORMER
FOR
DIRECT CURRENTS
P L Bradford
J H Fletcher.

Fig. 1.

side, being accomplished by adjusting the field rheostats.

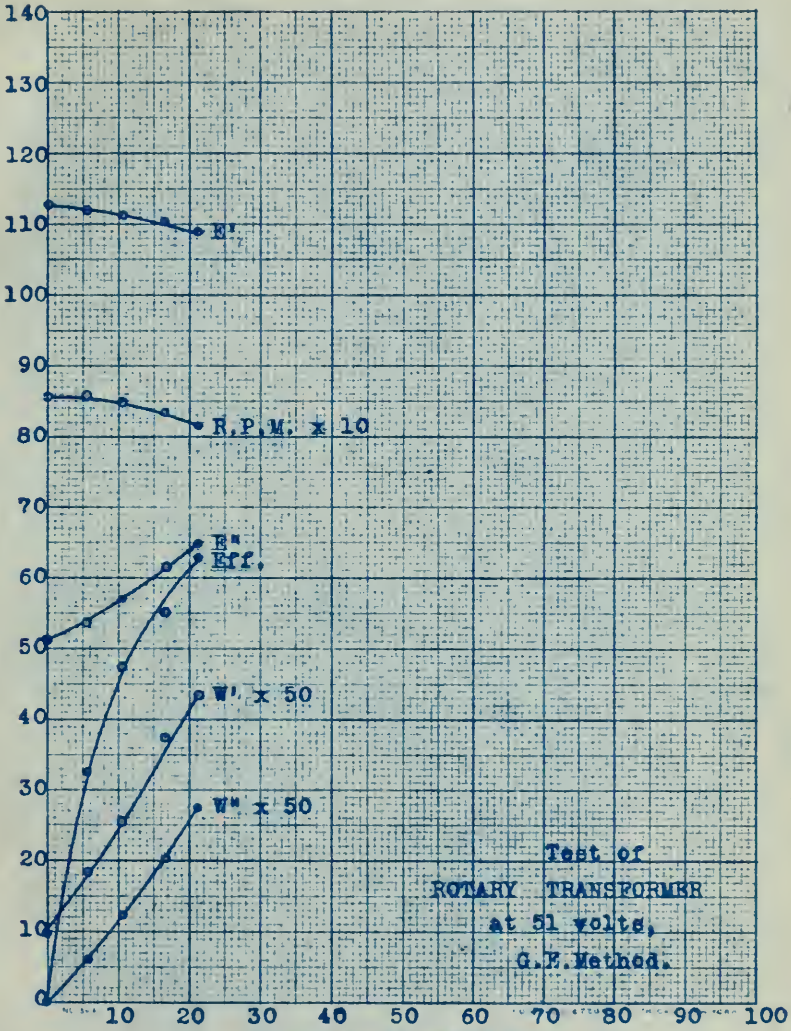
The machine as applied to the method of Crompton & Co., consists essentially of two independent magnetic circuits, with permantly connecten shunt windings in series; a regulatind rheostat may or may not be inserted. Each of these magnetic circuits is capable of running the machine independent of the other. It will be noted from the diagram that north and south poles of the motor have adjacent north or south poles in the generator portion. The motor brushes are in a fixed position on the vertical diameter of the commutator, and are connected to the line through a starting rheostat. The generator brushes are each independent and movable in the case of a variable voltage and fixed in a constant voltage machine at equal distances magnetically on either side of the motor brushes. The generator brushes are each connected through a compound winding to a common point, forming short circuited brushes. The load is connected between this junction and either side of the supply line, as shown in the diagram, (Fig. 4.).

The first type of machine, taken in consideration in this report, was a variable speed Stow Motor, #813, 110 volts, 6 H. P., 680 - 1510 r.p.m., chosen because of the lap winding of the armature, and adaptability of the yoke and brush gear. Connections were made as in figure I. The brushes (a, a) were made the motor brushes. The current being led through the starting rheostat from a single pole, single throw switch in the line. The double pole, single throw main line switch being closed, excites the motor field to its maximum value through the main field rheostat. The generator field rheostat, having all its resistence out in, excites the generator field coils, to a very low value. The motor having been brought up to speed and thrown on to the line, the double pole, single throw load switch, connecting with the brushes (b, b) to the load, was closed. The voltage regulation then consisted of the field rheostat regulation. Ammeters were placed in each field circuit, main circuit, and load circuit. Volt meters were placed acrossed the line and generator brushes (b, b), to measure input

ROTARY TRANSFORMER

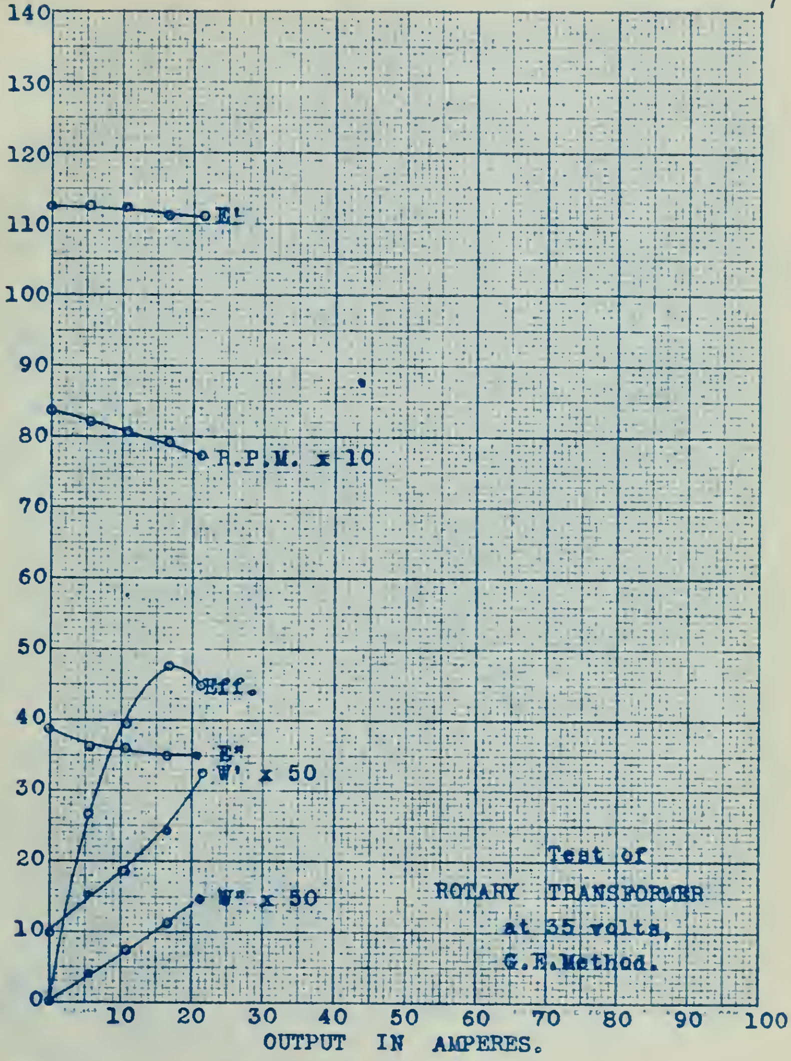
General Electric Method.

E_1	E_2	I_1	I_2	W_1	W_2	Eff%	Speed
112.5	51.0	4.4	0	495	0	0	858
112.0	53.6	8.2	5.6	918	300	8589	858
111.5	57.6	11.5	10.6	1281	605	47.3	848
110.5	61.5	17.0	16.8	1880	1034	55.0	836
109.0	65.0	19.8	21.1	2160	1370	63.2	819
112.5	38.8	4/4	0	495	0	0	837
112.5	36.1	6.7	5.6	754	202	26.8	819
112.5	36.0	8.5	10.6	914	382	39.8	810
111.5	35.0	11.0	16.8	1226	588	47.8	793
111.0	35.0	14.8	21.1	1642	744	44.8	774



Test of
ROTARY TRANSFORMER
at 51 volts,
G.E.Method.

OUTPUT IN AMPERES.

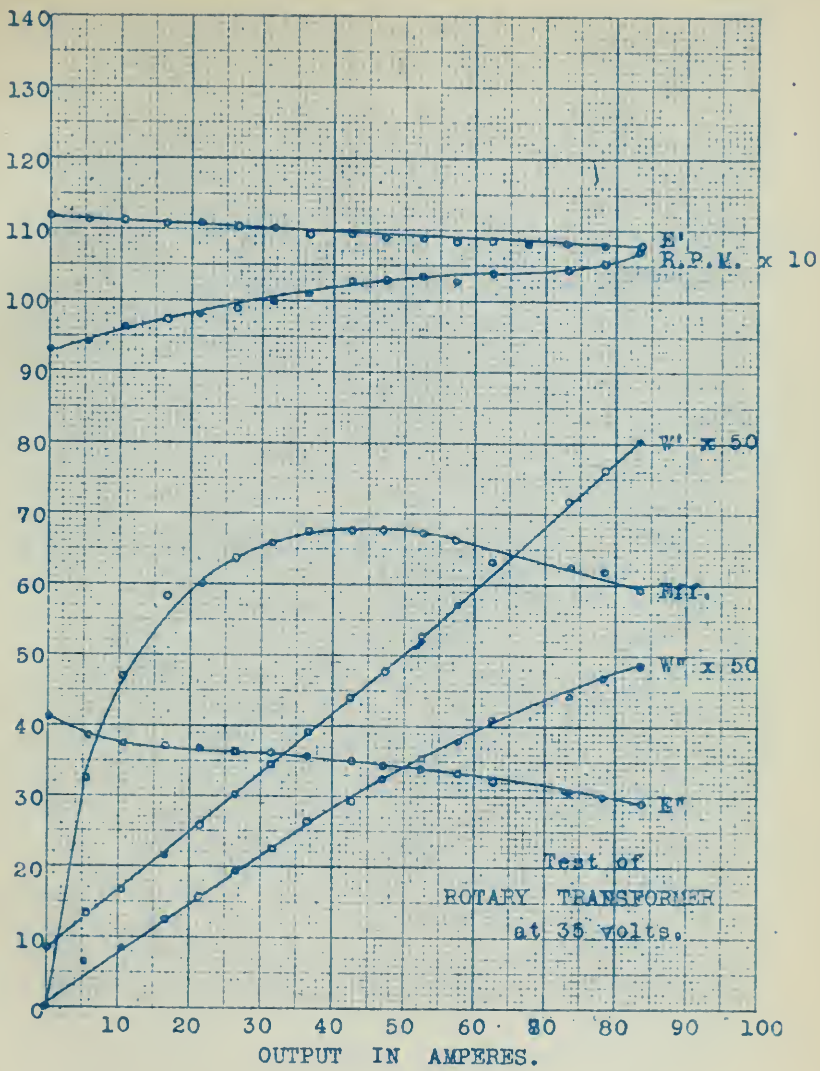


Test of
ROTARY TRANSFORMER
at 35 volts,
G.E.Method.

ROTARY TRANSFORMER

Multiple. Half Comp. English Method.

E_1	E_2	I_1	I_2	W_1	W_2	Eff%	Speed
112.0	41.1	3.8	0	425	0	0	929
111.5	38.5	5.9	5.6	658	328	32.5	944
111.5	37.9	7.6	10.6	848	402	47.1	965
111.0	37.4	9.7	16.8	1077	629	58.2	980
111.0	37.0	11.7	21.1	1300	781	60.0	982
110.5	36.7	13.7	26.4	1514	970	63.8	988
110.0	36.1	15.8	31.7	1740	1144	65.8	1000
109.5	35.8	17.8	36.8	1950	1318	67.5	1010
109.5	35.1	20.1	42.4	2200	1488	67.7	1029
109.0	34.5	22.0	47.1	2400	1624	68.0	1029
109.0	34.0	24.0	52.5	2650	1786	67.4	1038
108.5	33.0	26.4	57.6	2870	1900	66.3	1029
108.5	32.0	29.1	62.7	3160	2005	63.5	1038
108.0	30.2	32.8	73.2	3540	2210	62.5	1044
108.0	30.0	35.3	78.3	3818	2350	61.8	1053
108.0	29.0	37.2	83.4	4020	2424	59.7	1073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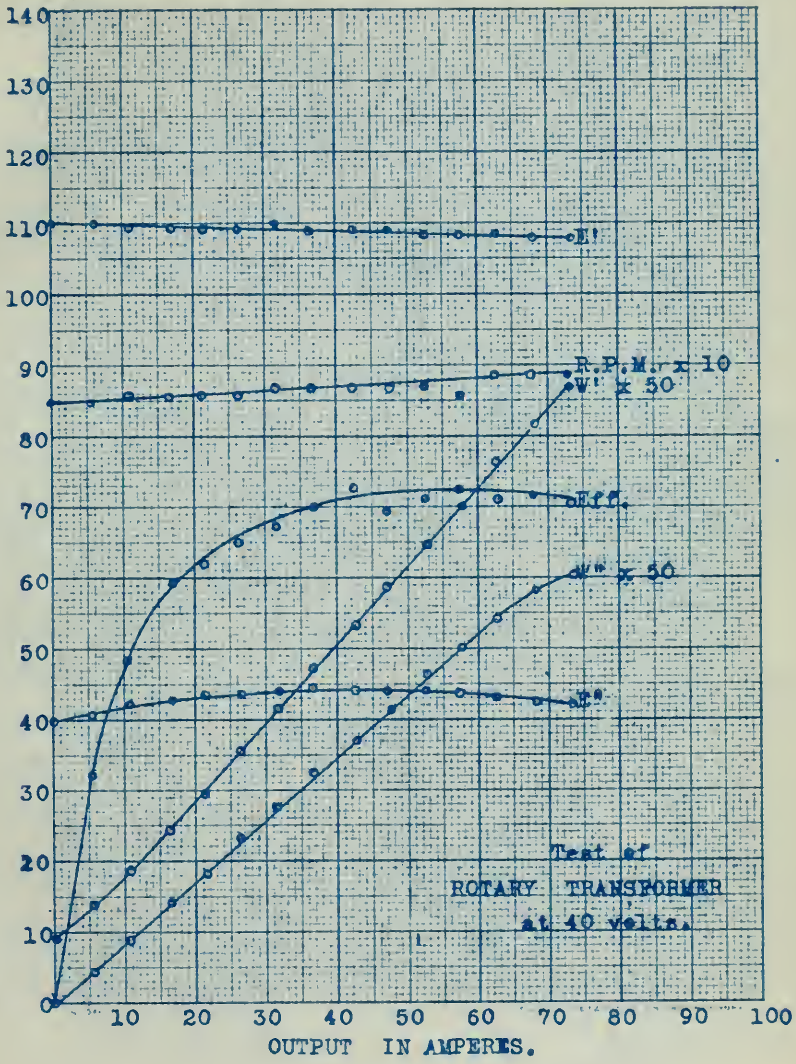
90
80
70
60
50
40
30
20
10
0
10
20
30
40
50
60
80
80
90
100
OUTPUT IN AMPERES.
E'
R.P.M. x 10
W' x 50
Eff.
W" x 50
E"
Test of
ROTARY TRANSFORMER
at 35 volts.

ROTARY TRANSFORMER							
Multiple. Full Comp. English Method.							
E_1	E_2	I	I_2	W_1	W_2	Eff%	Speed
110.0	40.0	4.1	0	452	0	0	849
110.0	40.9	6.3	5.6	693	229	32.5	849
109.5	42.2	8.5	10.6	931	448	48.3	858
109.5	42.8	11.1	16.8	1216	721	59.3	858
109.0	43.3	13.6	21.1	1484	914	61.9	858
109.0	43.8	16.3	26.4	1780	1158	65.0	858
110.0	44.0	18.9	31.7	2080	1394	67.2	868
109.0	44.5	21.6	36.8	2360	1650	69.8	877
109.0	44.0	24.3	42.4	2650	1865	72.9	877
109.0	44.0	27.4	47.1	2985	2073	69.4	877
108.5	44.0	29.9	52.5	3246	2310	71.2	877
108.5	43.8	32.4	57.6	3503	2503	72.6	858
108.5	43.2	35.2	62.7	3825	2710	71.0	884
108.0	42.8	37.8	68.0	4080	2910	71.4	884
108.0	42.0	40.3	73.2	4350	3073	70.7	884


140
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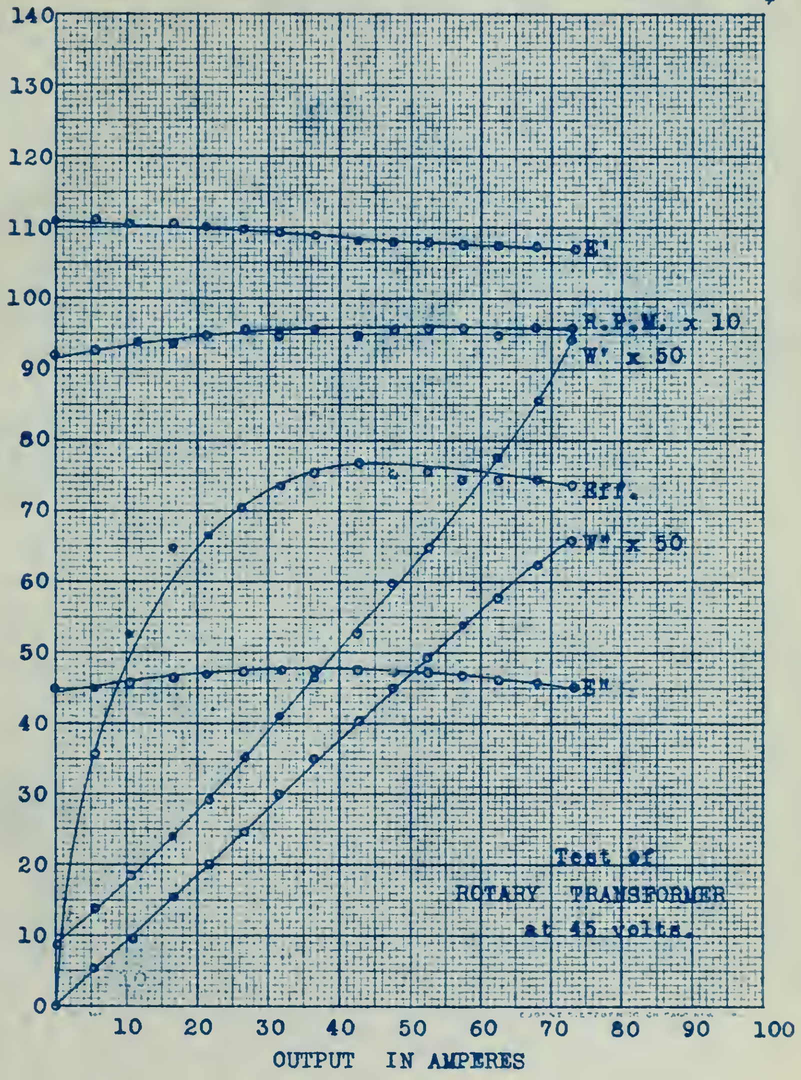
40
50
60
70
80
90
100
OUTPUT IN AMPERES.
E'
R.P.M. x 10
W' x 50
Eff.
W" x 50
E"
Test of
ROTARY TRANSFORMER
at 40 volts.

ROTARY TRANSFORMER

Multiple. Full Comp. English Method.

E_1	E_2	I_1	I_2	W_1	W_2	Eff%	Speed
111.0	45.1	3.8	0	422	0	0	921
111.0	45.1	6.3	5.6	700	253	36.0	929
110.5	45.8	8.4	10.6	928	485	52.3	939
110.5	46.5	10.8	16.8	1194	782	64.8	939
110.0	47.0	13.4	21.1	1470	992	66.6	949
110.0	47.2	16.1	26.4	1770	1245	70.5	958
109.5	47.4	18.7	31.7	2050	1500	73.4	949
109.0	47.8	21.4	36.8	2330	1760	75.1	958
108.5	47.6	24.3	42.4	2640	2019	76.8	949
108.0	47.4	27.6	47.4	2980	2256	75.0	958
108.0	47.1	30.2	52.5	3260	2470	75.9	958
107.5	47.0	33.2	57.6	3736	2710	76.4	958
107.5	46.2	36.2	62.7	3885	2890	74.4	949
107.5	45.8	38.9	68.0	4282	3113	74.5	957
107.0	45.1	41.8	73.2	4520	3300	73.9	957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80
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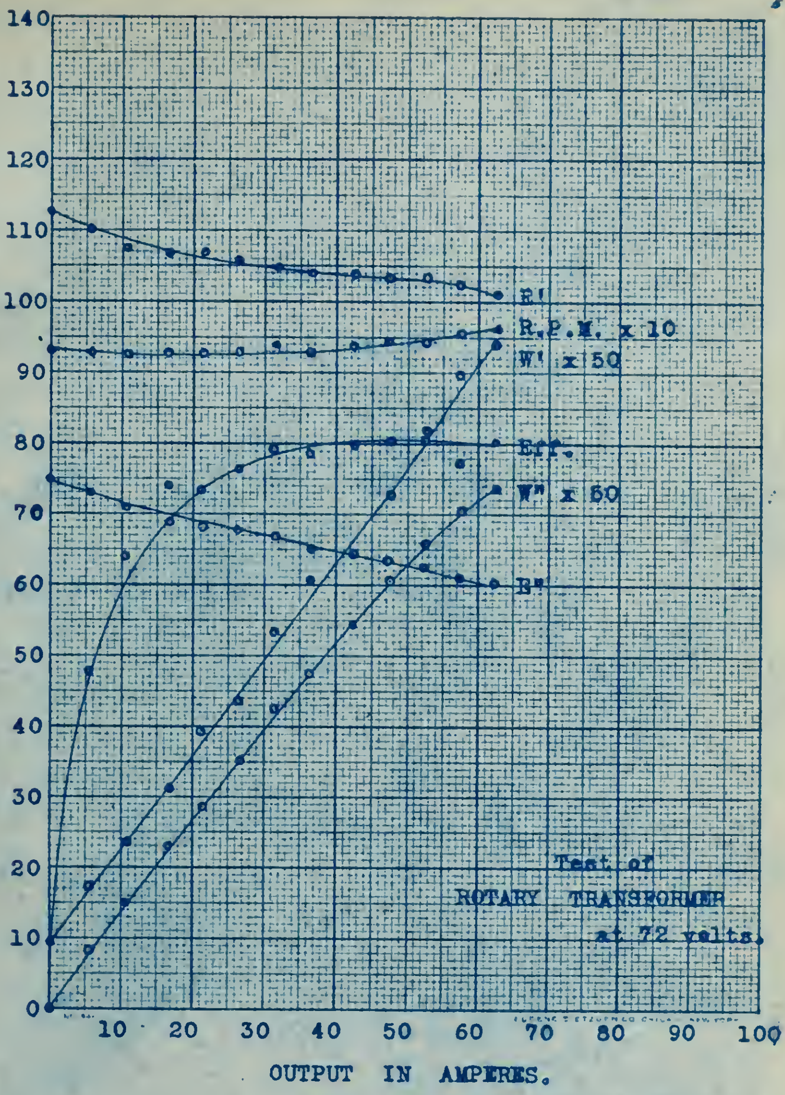
60
50
40
30
20
10
0
10
20
30
40
50
60
70
80
90
100
OUTPUT IN AMPERES
E'
R.P.M. x 10
W' x 50
Eff.
W" x 50
E"
Test of
ROTARY TRANSFORMER
at 45 volts.

ROTARY TRANSFORMER

Multiple. Half Comp. English Method.

E_1	E_2	I_1	I_2	W_1	W_2	Eff.%	Speed
112.5	75.0	4.1	0	462	0	0	929
110.0	73.0	7.8	5.6	858	469	47.9	929
107.5	71.0	11.0	10.6	1184	753	62.9	929
107.0	69.0	14.7	16.8	1570	1158	74.2	929
107.0	68.4	18.3	21.1	1964	1440	73.6	929
106.0	68.0	22.0	26.4	2337	1793	76.5	929
105.0	67.0	25.5	31.7	2680	2122	79.4	936
104.0	65.0	29.2	36.8	3041	2391	78.8	938
104.0	64.2	32.9	42.4	3424	2724	79.8	938
103.5	63.8	36.2	47.1	3745	3005	80.4	944
103.5	62.6	39.6	52.5	4100	3285	80.3	944
102.5	61.1	43.8	57.6	4502	3520	77.4	954
101.0	60.4	46.6	62.7	4700	3782	80.4	963

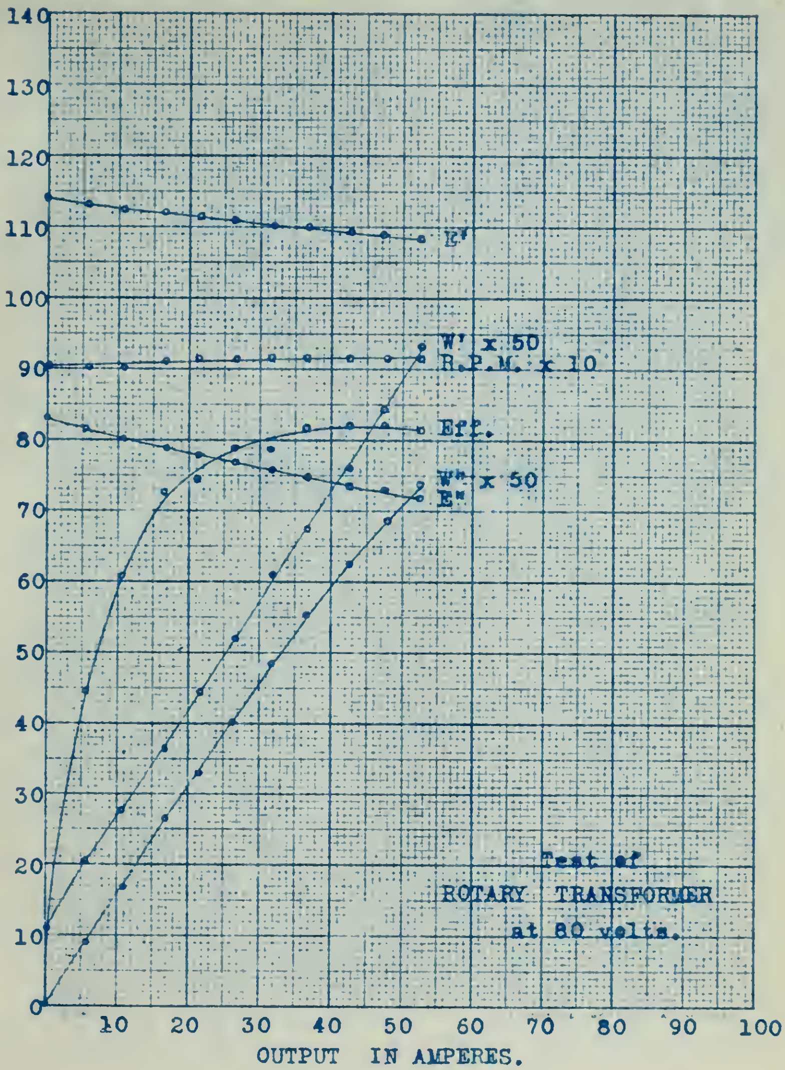


Test of
ROTARY TRANSFORMER
at 72 volts.

ROTARY TRANSFORMER

Multiple. Half Comp. English Method.

E_1	E_2	I_1	I_2	W_1	W_2	Eff%	Speed
114.0	83.0	4.8	0	546	0	0	900
113.0	81.1	9.0	5.6	1016	454	44.5	900
112.5	80.0	12.4	10.6	1395	848	60.7	900
112.0	79.0	16.3	16.8	1826	1326	72.5	914
111.5	78.0	19.8	21.1	2210	1644	74.4	914
111.0	77.0	23.2	26.4	2576	2030	78.9	914
110.0	76.6	27.5	31.7	3030	2416	79.6	914
110.0	75.0	30.7	36.8	3380	2760	81.7	914
109.0	73.8	34.9	42.4	3810	3130	82.0	914
109.0	73.0	38.5	47.1	4200	3430	82.0	914
108.5	71.8	42.8	52.5	4650	3770	81.2	914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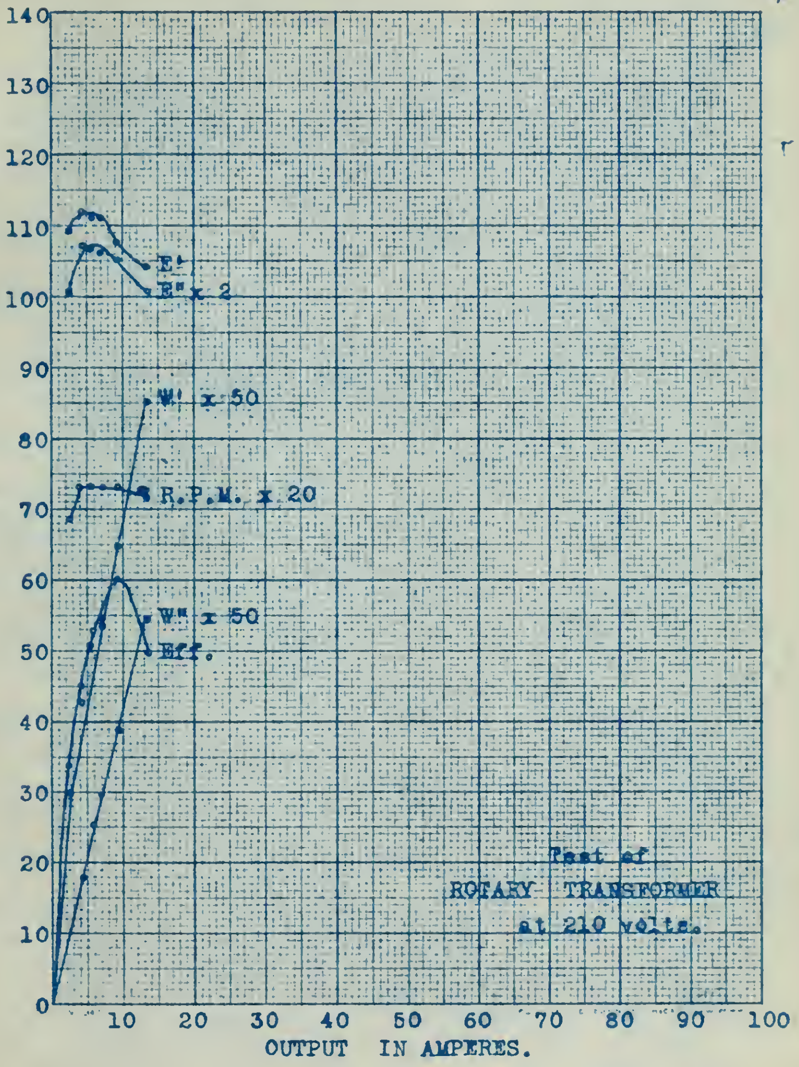
70
80
90
100
OUTPUT IN AMPERES.
E'
W' x 50
R.P.M. x 10
Eff.
W" x 50
E"
Test of
ROTARY TRANSFORMER
at 80 volts.

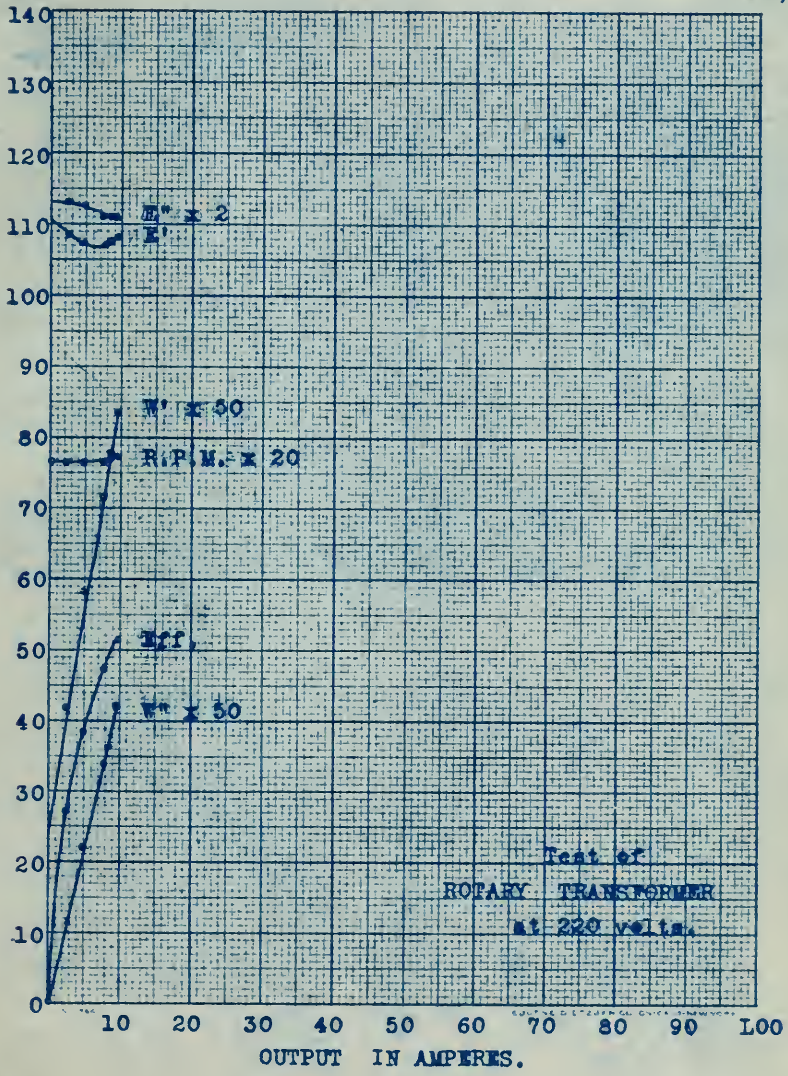
ROTARY TRANSFORMER

Step-up. Full Comp. English Method.

E_1	E_2	I_1	I_2	W_1	W_2	Eff %	Speed
109.0	201	13.5	2.5	1470	505	34.0	1370
111.5	214	19.1	4.1	2130	878	44.9	1460
111.0	213	21.0	5.5	2330	1170	50.0	1460
111.0	213	23.7	5.9	2630	1255	49.2	1460
111.0	212	24.5	7.0	2720	1483	53.7	1460
107.5	210	30.0	9.2	3224	1930	60.0	1460
104.0	201	41.0	13.3	4270	2670	59.6	1426
108.5	226	19.3	2.5	2096	565	27.0	1534
107.0	225	27.2	4.9	2910	1100	38.3	1534
107.0	220	33.3	7.7	3565	1694	47.6	1534
107.5	222	36.2	8.2	3894	1320	47.9	1552
108.0	222	38.6	9.4	4170	2090	51.3	1552



Test of
ROTARY TRANSFORMER
at 210 volts.

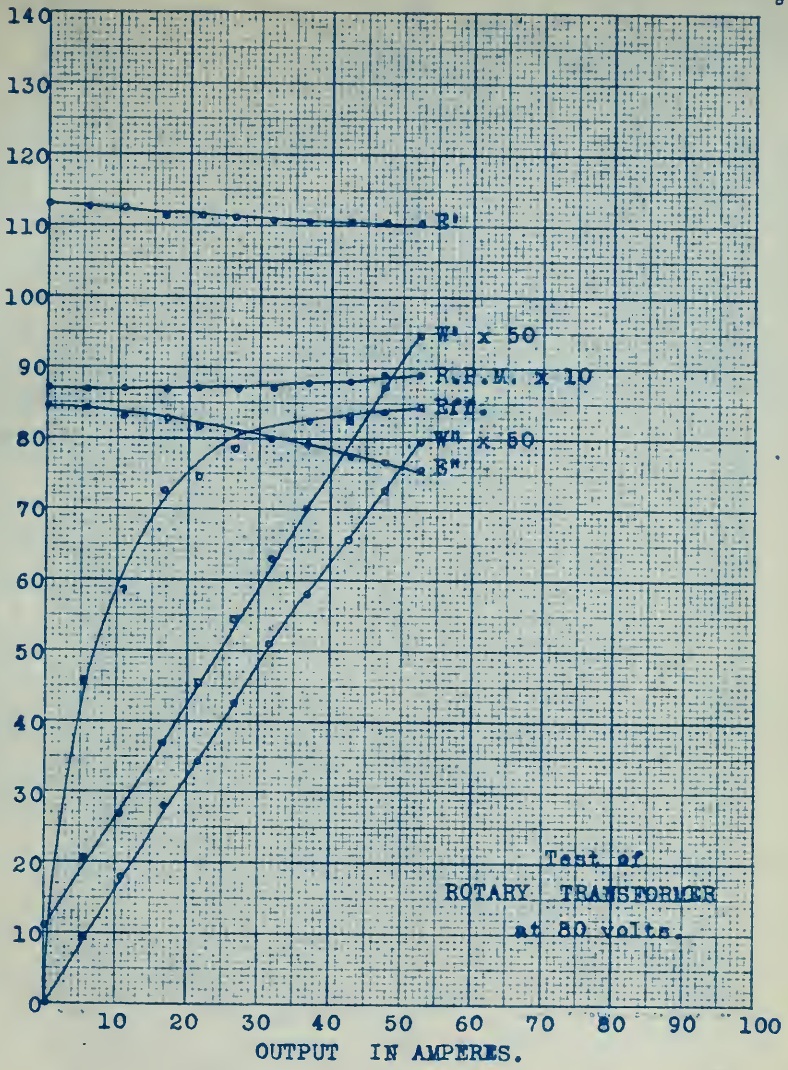


Test of
ROTARY TRANSFORMER
at 220 volts.

ROTARY TRANSFORMER

Multiple. Full Comp. English Method.

E_1	E_2	I_1	I_2	W_1	W_2	Eff%	Speed
113.0	84.8	4.8	0	543	0	0	868
113.0	84.6	9.1	5.6	1028	474	46.0	868
112.5	83.0	11.9	10.6	1339	880	58.4	868
111.5	88.2	16.4	16.8	1829	1379	72.7	868
111.5	81.5	20.2	21.1	2250	1719	74.6	868
111.0	80.2	24.3	26.4	2700	2115	78.5	868
110.5	79.6	28.4	31.7	3150	2520	80.0	868
110.5	78.5	31.8	36.8	3501	2880	82.2	877
110.5	77.5	36.0	42.4	4160	3288	82.5	877
110.0	76.9	39.5	47.1	4350	3620	83.4	884
110.0	75.5	42.9	52.5	4720	3960	84.0	884


140
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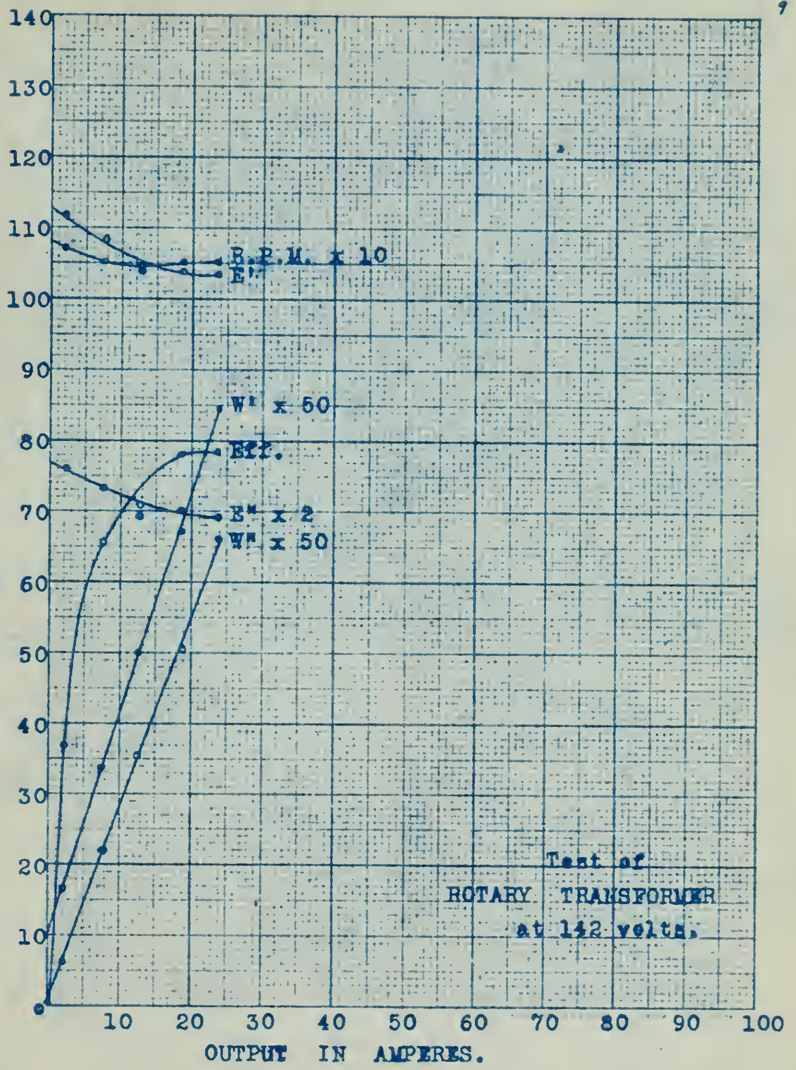
60
70
80
90
100
OUTPUT IN AMPERES.
E'
W' x 50
R.P.M. x 10
Eff.
W" x 50
E"
Test of
ROTARY TRANSFORMER
at 80 volts.

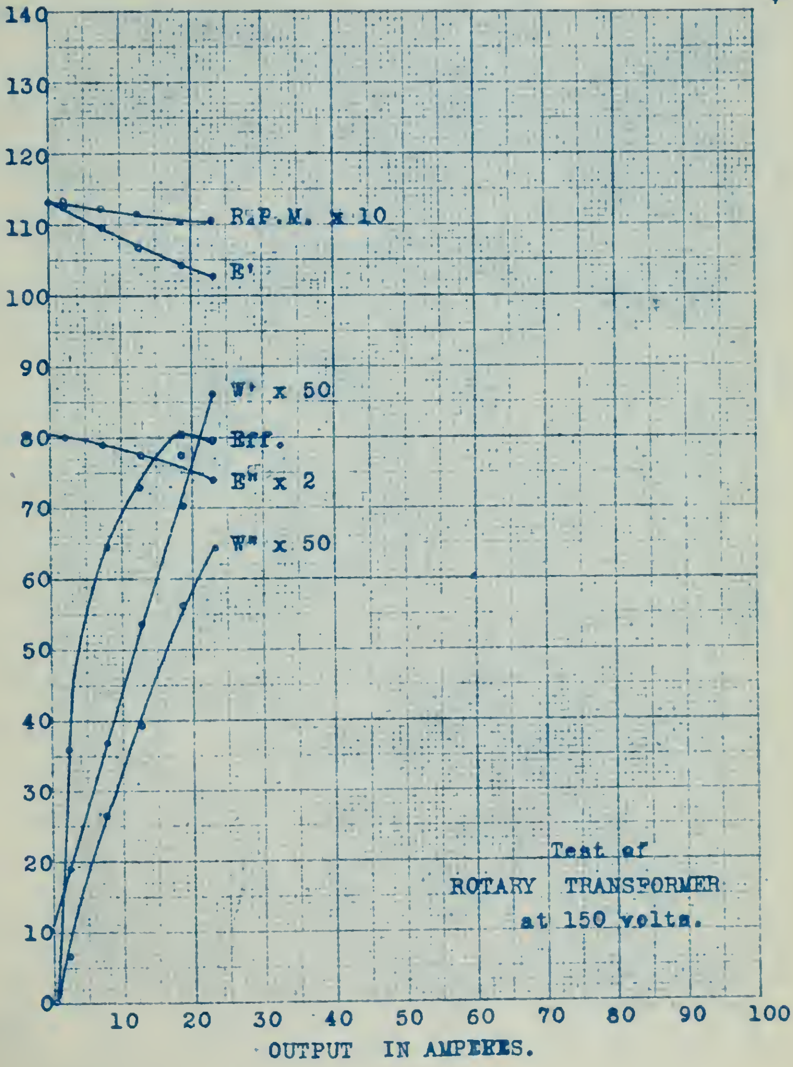
ROTARY TRANSFORMER

Step-up. Full Comp. English Method.

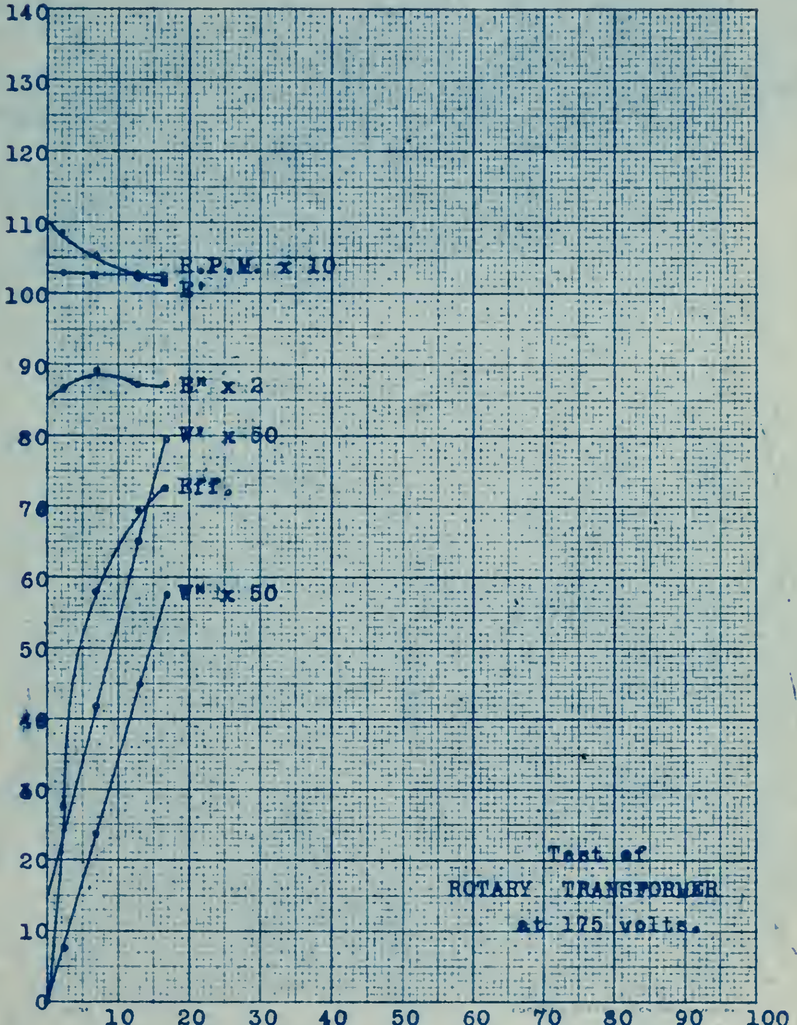
E_1	E_2	I_1	I_2	W_1	W_2	Eff %	Speed
111.5	1522	7.4	2.0	825	304	3370	01078
108.0	146	15.5	7.5	1674	1096	65.7	1050
104.5	141	23.9	12.5	2500	1762	69.2	1041
104.0	140	32.2	18.7	3350	2615	78.1	1050
103.5	138	40.8	23.9	4230	3300	75.0	1050
112.5	160	8.3	2.1	935	336	36.0	1132
109.5	158	17.2	7.7	1884	1318	64.4	1122
106.5	155	25.2	12.6	2684	1954	72.8	1115
104.0	150	33.7	18.8	3508	2820	80.4	1102
102.5	148	42.0	23.0	4300	3404	79.4	1096
108.5	173	12.5	2.2	1357	380	28.0	1034
105.0	178	19.8	6.7	2080	1192	57.7	1235
102.5	174	31.7	12.8	3252	2232	69.1	1226
101.5	174	39.0	16.4	3970	2854	72.3	1226



Test of
ROTARY TRANSFORMER
at 142 volts.



Test of
ROTARY TRANSFORMER
at 150 volts.



OUTPUT IN AMPERES.

and output voltage. No speed recording device was used.

This method did not prove entirely satisfactory. The machine raced dangerously when the load was applied; this is due to the fact that the pole flux remained at a practically constant value, with a large increase of current through portions of the armature curcuit.

$$\text{Since} \quad I = \frac{F}{H\,l}$$

when I = Current

F = Force

H = Field Strength

l = Length of Inductor

Any increase in I will produce a corresponding increase in F; H and l remaining constant, therefore the result of this increased force is increased speed.

Serious sparking occured at all brushes, partly due to the inductors of the drum winding, where each coil had a pitch of one pole, and partly due to magnetic leakage. There occurred a rapid rise in temperature of both armature and commutator due to sparking at the commutator and conduction into the armature core. Also to

heavy currents in portions of the rotating member.

In this particular type of motor the bearings were carried in heavy cast-iron arms which connected the yoke across the generator field poles, resulting in a large leakage flux. Leakage flux between poles was so great that the effect of field regulation was very small. Data obtained from the leakage test using one loop of wire around the part to be tested, connected to a milivolt meter showed the following results:

Position 1, between S motor and N Generator field, 2 m.v.

Position 2, between N motor and N generator field, 11.8 m.v.

Position 3, between N motor and S generator field, 4 m.v.

Position 4, between S generator and S motor field, 13 m.v.

The arms giving respectively 18 and 14 mili volts.

The results of the test upon the Stow motor show a high efficiency considering the troubles met with in its construction, but the efficiency is below practical op-

eration. The load voltage is very unstable, with an increase of load there is a corresponding decrease in voltage. This ranges from 117 volts at 0 to 43.5 volts at 38.5 amperes, the motor voltage varying but slightly with an increase of current. These results are plotted on the accompanying curve sheet.

The second test was performed on the six phase, General Electric Rotary Converter,#17721, Type A.C.S., Form A, Class, 4 - 10 - 750, Speed 750, Constant Current 880 amperes, at 125 volts, Alternating Current 25 cycles, 85 volts.

The slip rings of the rotary were electrically disconnected, and the loose ends of the armature securely tapped to prevent short-circuiting of the inductors. The lower two poles of the frame were selected as the generator poles and a series winding of twenty-four turns of #8 double cotton covered wire was placed on each,as shown in figure II. The brushes were mechanically rigid but electrically insulated from each other.

This machine was first tested with a shunt field connected in series. The supply line was connected through the starting rheostat to the motor brushes (a, a), as in-

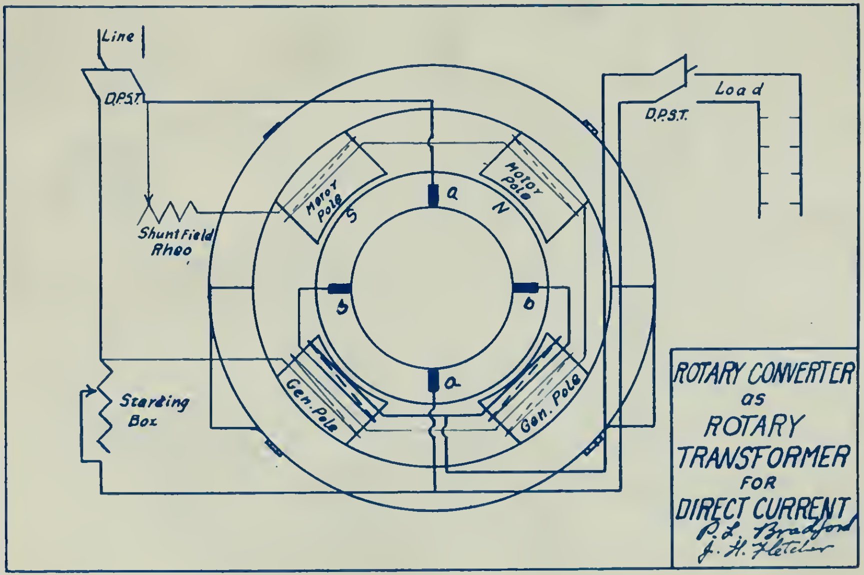

Line
D.P.S.T.
Shunt Field
Rheo
Starting
Box
Motor
Pole
S
Motor
Pole
N
a
b
b
a
Gen. Pole
Gen. Pole
D.P.S.T.
Load
ROTARY CONVERTER
as
ROTARY
TRANSFORMER
FOR
DIRECT CURRENT
P. L. Bradford
J. H. Fletcher

Fig. 2.

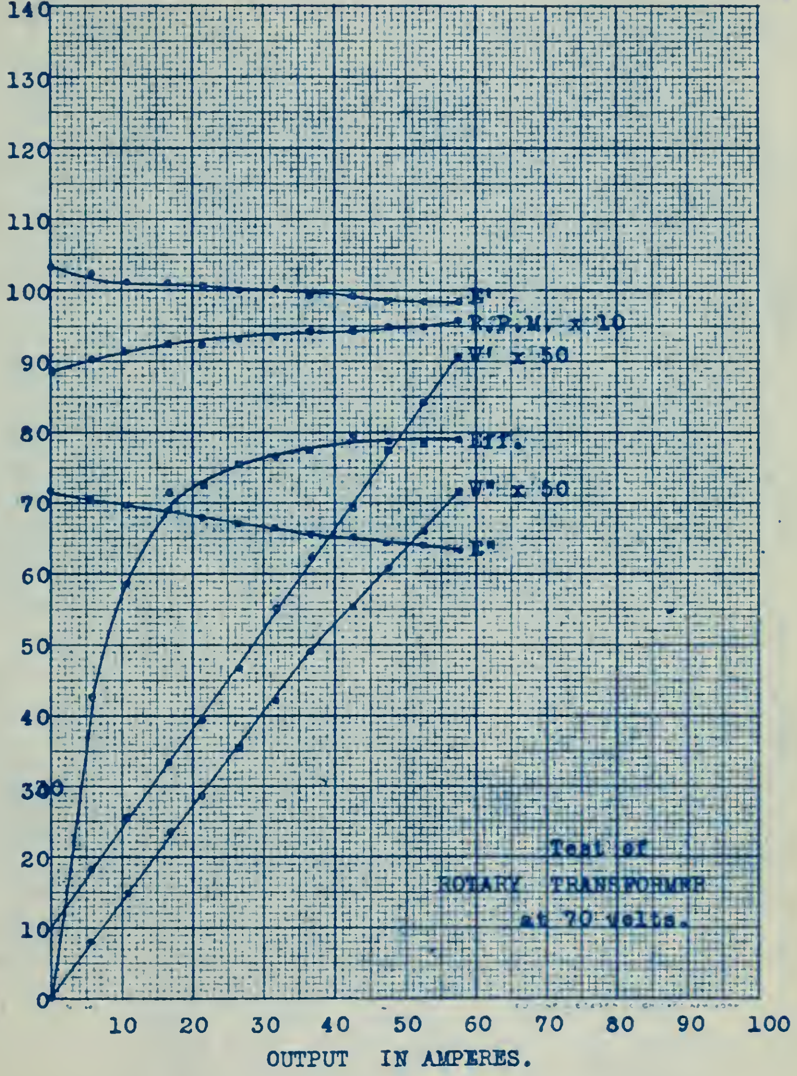
dicated in Fig. 3. The load was connected to the generator terminals, (b, b), through a double pole, single throw switch. The compound winding was not connected during this test. Ammeters were placed, in the shunt field, main line, and load circuit. Voltmeters were placed across the supply line and the load. In this test the machine raced with an increase of load, excessive sparking occured at all brushes, the commutator and armature became hot at low loads. The voltage regulation was extremely poor, in all cases falling approximately fifty per cent, at half load, the motor voltage varying but slightly. The maximum efficiency attained by this machine occurred at a generator voltage of 84, and a load of 50 amperes, giving an efficiency of fifty-three per cent. No speed recording devise was used, but at this point the machine was racing dangerously.

The second method used in testing, the G. E. Rotary Converter is shown diagrammatically in Fig. 2. The motor current was supplied to the motor brushes, (a, a); the shunt field was connected in series to the controlling rheostat and the supply circuit. Leads

ROTARY TRANSFORMER

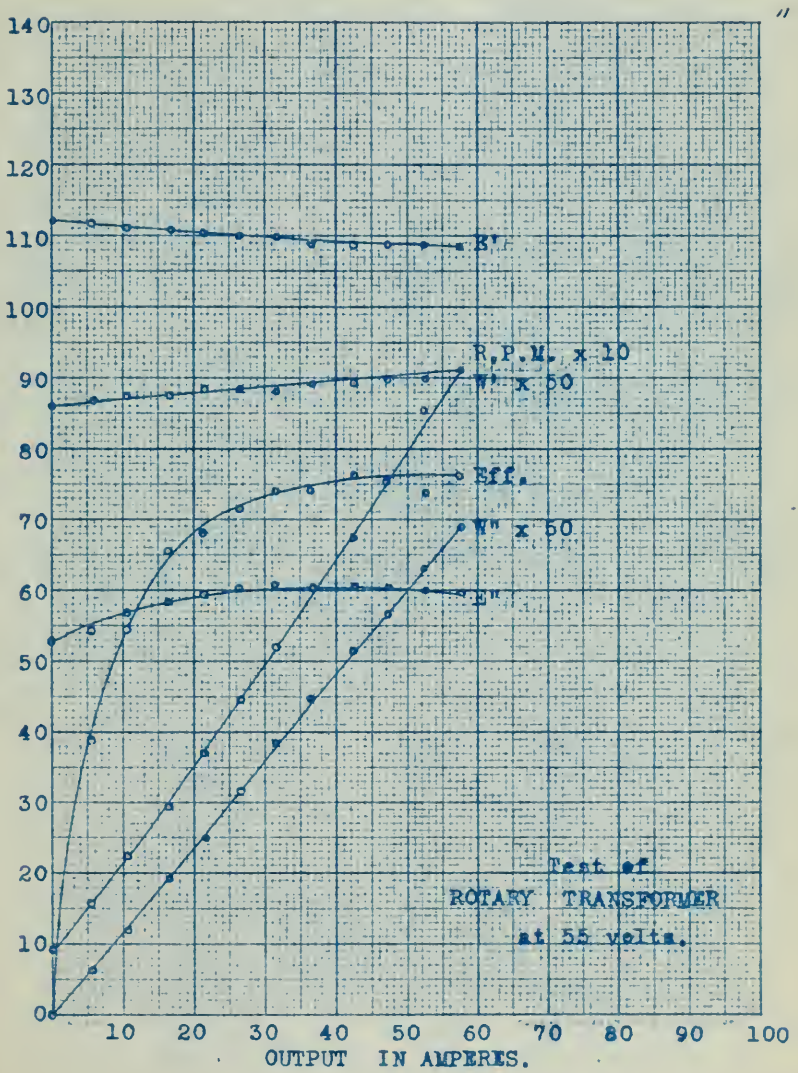
Multiple. Half Comp. English Method.

E_1	E_2	I_1	I_2	W_1	W_2	Eff%	Speed
113.0	71.9	4.4	0	498	0	0	885
112.0	70.4	8.2	5.6	920	394	42.7	900
111.0	69.9	11.4	10.6	1265	740	58.3	914
111.0	69.0	14.6	16.8	1628	1160	71.7	924
110.5	68.0	17.8	21.1	1970	1432	72.6	924
110.0	67.1	21.3	26.4	2340	1770	75.6	932
110.0	66.5	25.0	31.7	2750	2110	76.6	932
109.0	65.6	28.6	36.8	3120	2450	77.5	940
109.6	65.0	31.7	42.4	3455	2758	79.6	940
108.5	64.1	35.5	47.1	3860	3020	78.6	949
108.5	62.9	38.7	52.5	4200	3300	78.5	949
108.0	62.2	42.0	57.6	4535	3580	79.1	959


140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
10
20
30
40
50
60
70
80
90
100
OUTPUT IN AMPERES.
F'
R.P.M. x 10
V' x 50
Eff.
V" x 50
F"
Test of
ROTARY TRANSFORMER
at 70 volts.

''

ROTARY TRANSFORMER							
Multiple. Full Comp. English Method.							
E_1	E_2	I_1	I_2	W_1	W_2	Eff %	Speed
112.0	52.8	4.2	0	470	0	0	858
111.5	54.4	7.0	5.6	781	340	39.0	868
111.0	57.0	10.1	10.6	1121	604	54.2	877
111.0	58.2	13.4	16.8	1486	976	65.9	877
110.5	59.4	16.7	21.1	1860	1252	68.2	885
110.0	60.5	20.3	26.4	2234	1596	71.4	885
110.0	60.8	23.6	31.7	2600	1925	74.0	885
109.0	60.8	27.6	36.8	3013	2240	74.5	894
109.0	60.8	31.0	42.4	3383	2580	76.4	894
109.0	60.4	34.7	47.1	3784	2840	75.2	900
109.0	60.1	39.2	52.5	4275	3154	74.0	900
108.5	59.8	41.6	57.6	4520	3450	76.4	914

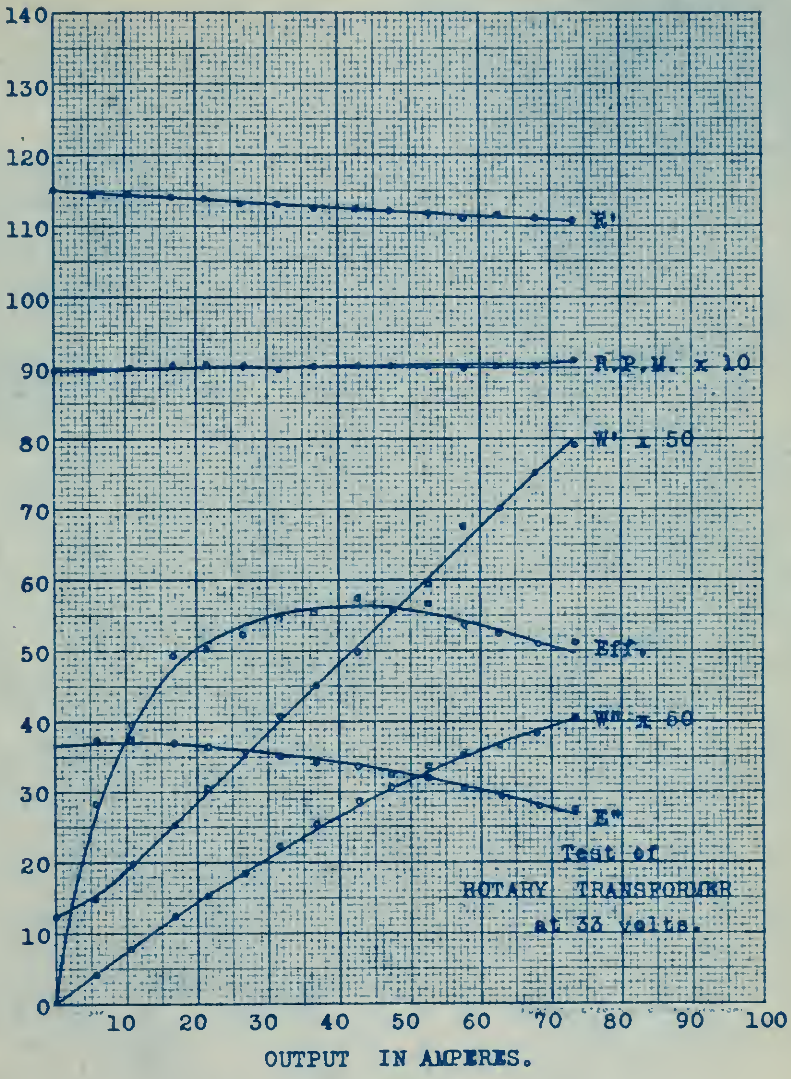


Test of
ROTARY TRANSFORMER
at 55 volts.

ROTARY TRANSFORMER

Multiple. Full Comp. English Method.

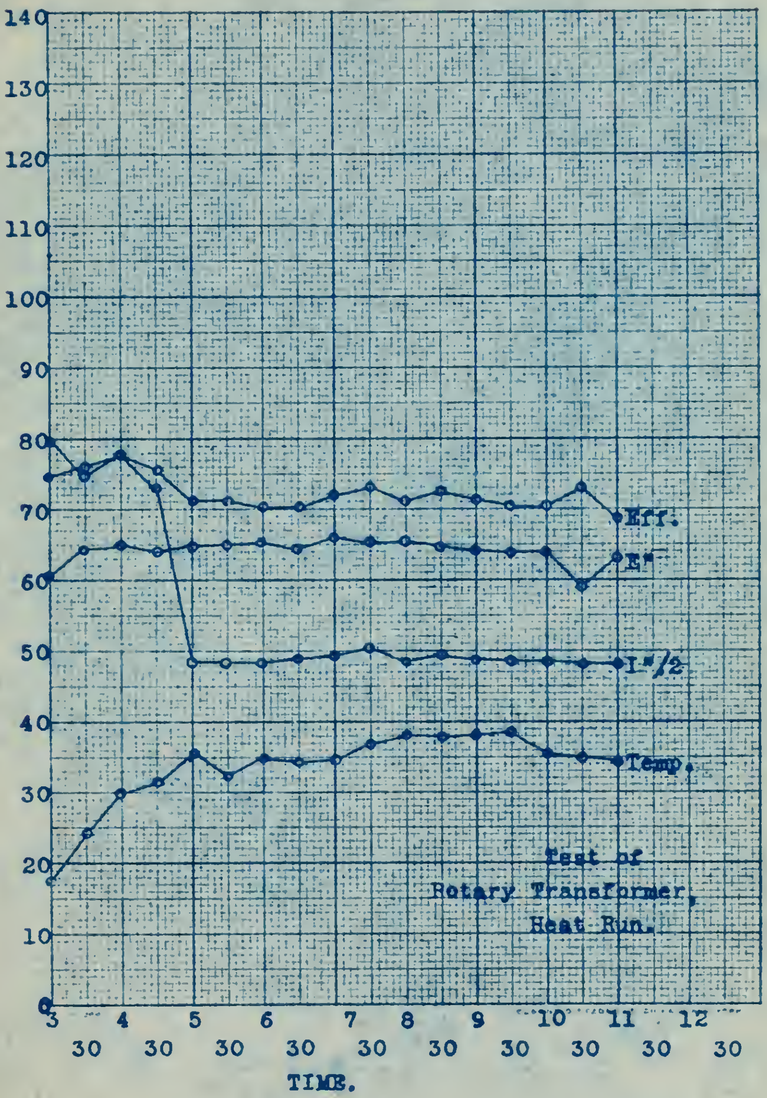
E_1	E_2	I_1	I_2	W_1	W_2	Eff%	Speed
115.0	36.5	5.26	0	605	0	0	893
114.5	37.2	6.45	5.6	74 0	208	28.2	893
114.5	37.2	8.65	10.6	990	395	39.9	900
114.0	36.8	11.0	16.8	1254	618	49.1	900
114.0	36.1	13.3	21.1	1516	763	50.0	900
113.0	35.2	15.7	26.44	1790	929	52.2	900
113.0	35.0	18.0	31.7	2034	1109	54.4	893
112.5	34.0	20.0	36.8	2252	1250	55.4	900
112.5	33.7	22.0	42.4	2478	1430	57.7	900
112.0	32.6	24.7	47.1	2767	1534	55.5	900
111.5	32.0	26.6	52.5	2965	1680	56.6	900
111.0	30.5	29.4	57.6	3364	1756	53.8	900
111.0	29.0	31.5	62.7	3508	1813	52.1	900
111.0	28.0	33.8	68.0	3750	1904	50.8	900
110.5	27.5	35.7	73.2	3950	2014	51.0	910


140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
E'
R.P.M. x 10
W' x 50
Eff.
W" x 50
E"
Test of
ROTARY TRANSFORMER
at 33 volts.
10
20
30
40
50
60
70
80
90
100
OUTPUT IN AMPERES.

ROTARY TRANSFORMER

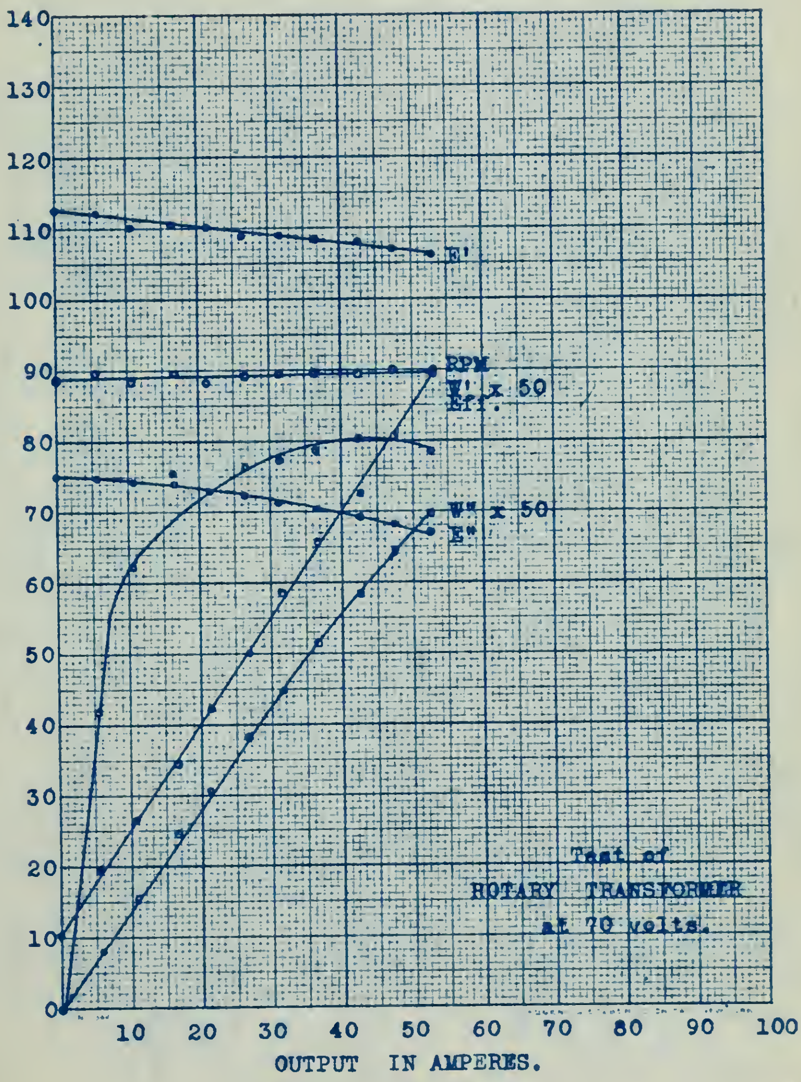
Heat Run. Full Comp. English Method.

E_1	E_2	I_1	I_2	Eff	Time	Temp	Speed
111.5	61.0	29.2	39.7	74.5	3:00	17.5	890
110.0	64.6	29.0	37.5	76.0	3:30	24.1	890
110.5	65.0	29.3	38.8	77.8	4:00	30.0	900
110.0	64.0	29.0	37.5	75.6	4:30	31.5	900
111.0	65.0	19.8	24.2	71.2	5:00	35.5	900
110.0	65.0	20.0	24.1	71.1	5:30	32.5	900
111.0	65.3	20.2	24.1	70.2	6:00	35.0	900
111.5	64.5	20.3	24.5	70.4	6:30	34.5	900
111.6	66.2	20.3	24.6	72.0	7:00	34.5	900
110.0	65.1	20.3	25.1	73.1	7:30	37.0	900
111.0	65.4	20.2	24.2	71.1	8:00	38.5	900
110.5	64.8	19.9	24.6	72.3	8:30	38.0	900
111.0	64.1	19.8	24.3	71.2	9000	38.0	900
110.5	63.8	19.8	24.3	70.3	9:30	38.5	900
112.5	64.0	19.6	24.2	70.3	10:00	35.5	909
106.0	59.0	18.3	24.0	73.0	10:#0	35.0	862
114.0	63.0	19.4	24.1	68.6	11:00	34.1	909



Test of
Rotary Transformer,
Heat Run.

ROTARY TRANSFORMER							
Multiple. Full Comp. English Method.							
E_1	E_2	I_1	I_2	W_1	W_2	Eff %	Speed
112.5	75.2	4.5	0	507	0	0	885
112.0	74.8	8.9	5.6	990	417	41.9	896
110.0	74.5	12.0	10.6	1332	790	62.3	885
110.5	74.0	15.6	16.8	1724	1240	75.4	896
110.0	73.2	19.2	21.1	2110	1543	73.1	885
109.0	72.5	22.9	26.4	2500	1914	76.5	896
109.0	71.2	26.7	31.7	2915	2250	77.6	896
108.5	70.2	30.3	36.8	3290	2580	78.6	896
108.0	69.2	33.7	42.4	3640	2930	80.5	896
107.0	68.2	37.5	47.1	4020	3210	80.1	900
106.5	67.0	42.1	52.5	4480	3501	78.5	900

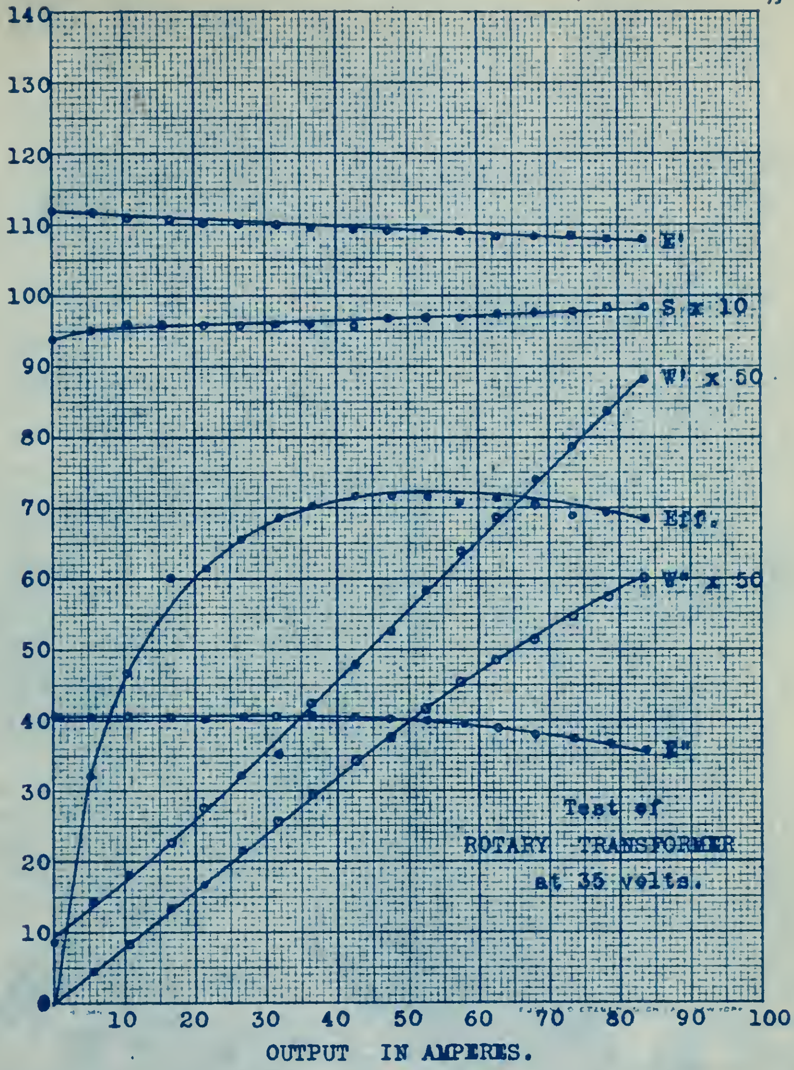


Test of
ROTARY TRANSFORMER
at 70 volts.

ROTARY TRANSFORMER

Multiple. Full Comp. English Method.

E_1	E_2	I_1	I_2	W_1	W_2	Eff %	Speed
112.0	40.1	4.0	0	448	0	0	940
111.5	40.2	6.3	5.6	702	225	32.0	950
111.0	40.3	8.2	10.6	911	428	46.8	959
110.5	40.3	10.2	16.8	1129	678	60.0	959
110.0	40.2	12.6	21.1	1387	850	61.3	959
110.0	40.6	14.8	26.4	1630	1072	65.9	959
110.0	40.7	16.0	31.7	1760	1290	68.7	959
109.5	40.7	19.4	36.8	2124	1496	70.5	959
109.5	40.2	21.8	42.4	2390	1704	71.6	959
109.0	40.1	24.1	47.1	2626	1889	71.8	967
109.0	40.0	26.8	52.5	2920	2100	71.8	967
109.0	39.4	29.4	57.6	3204	2270	70.8	967
108.5	38.9	31.6	62.7	3430	2440	71.3	977
108.5	38.1	34.1	68.0	3700	2590	70.0	977
108.5	37.6	36.4	73.2	3950	2750	69.0	977
108.0	36.8	38.6	78.4	4170	2894	69.3	986
108.0	36.0	40.7	83.6	4400	3010	68.5	986

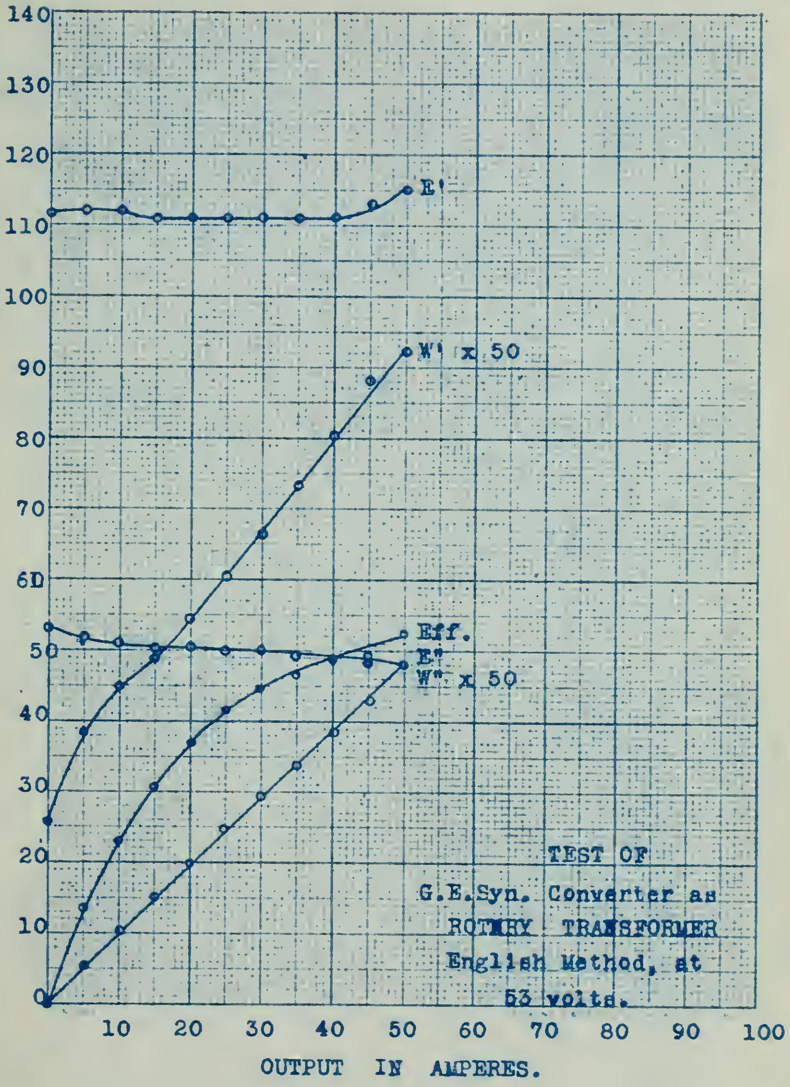


Test of
ROTARY TRANSFORMER
at 35 volts.

ROTARY TRANSFORMER

G.E.Syn. Converter. English Method.

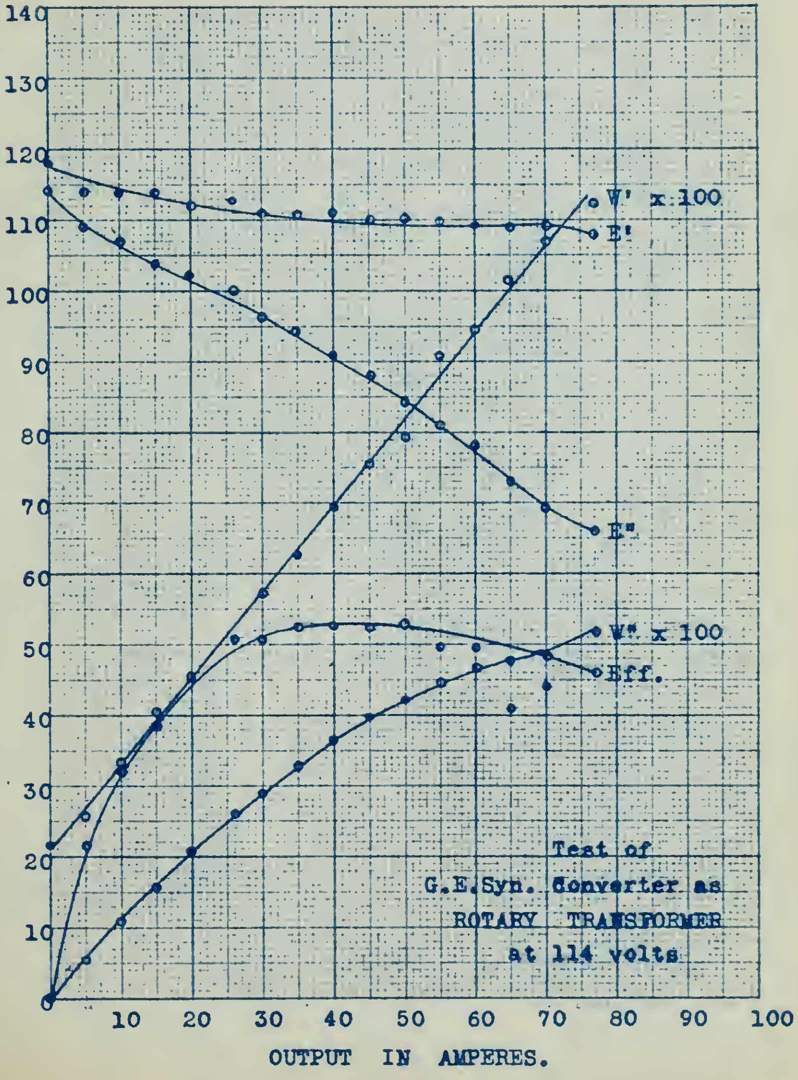
E_1	E_2	I_1	I_2	W_1	W_2	Eff%	Speed
111.5	53.0	14.7	0	1290	0	0	
112.0	52.0	17.2	5.0	1926	260	13.5	
112.0	51.0	20.0	10.0	2240	510	22.8	
111.0	50.5	22.1	15.0	2454	758	30.9	
111.0	50.0	24.4	20.0	2710	1000	37.0	
111.0	50.0	27.0	25.0	3000	1250	41.6	
111.0	49.2	30.0	30.0	3330	1476	44.8	
111.0	48.5	33.0	35.0	3665	1696	46.3	
111.0	48.0	36.0	40.0	4000	1920	48.0	
113.0	48.0	39.0	45.0	4400	2160	49.2	
115.0	48.0	40.0	50.0	4600	2400	52.3	
116.0	49.0	38.0	45.0	4415	2205	49.9	
116.0	50.0	32.5	35.0	3770	1750	46.4	
116.0	51.0	30.0	30.0	3480	1530	43.9	
117.0	51.0	27.8	25.0	3254	1275	39.2	
116.0	52.0	25.0	20.0	2900	1040	35.9	
110.0	51.0	23.0	17.0	2530	868	34.3	
116.0	53.0	22.5	15.0	26.0	766	29.4	
116.0	53.0	20.0	10.0	2320	530	22.8	
117.0	54.0	18.0	5.0	2110	270	12.8	
115.0	54.0	15.2	0	1748	0	0	


140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
E'
W' x 50
Eff.
E"
W" x 50
TEST OF
G.E.Syn. Converter as
ROTARY TRANSFORMER
English Method, at
53 volts.
10
20
30
40
50
60
70
80
90
100
OUTPUT IN AMPERES.

ROTARY TRANSFORMER

G.E.Syn. Converter. G.E.Method.

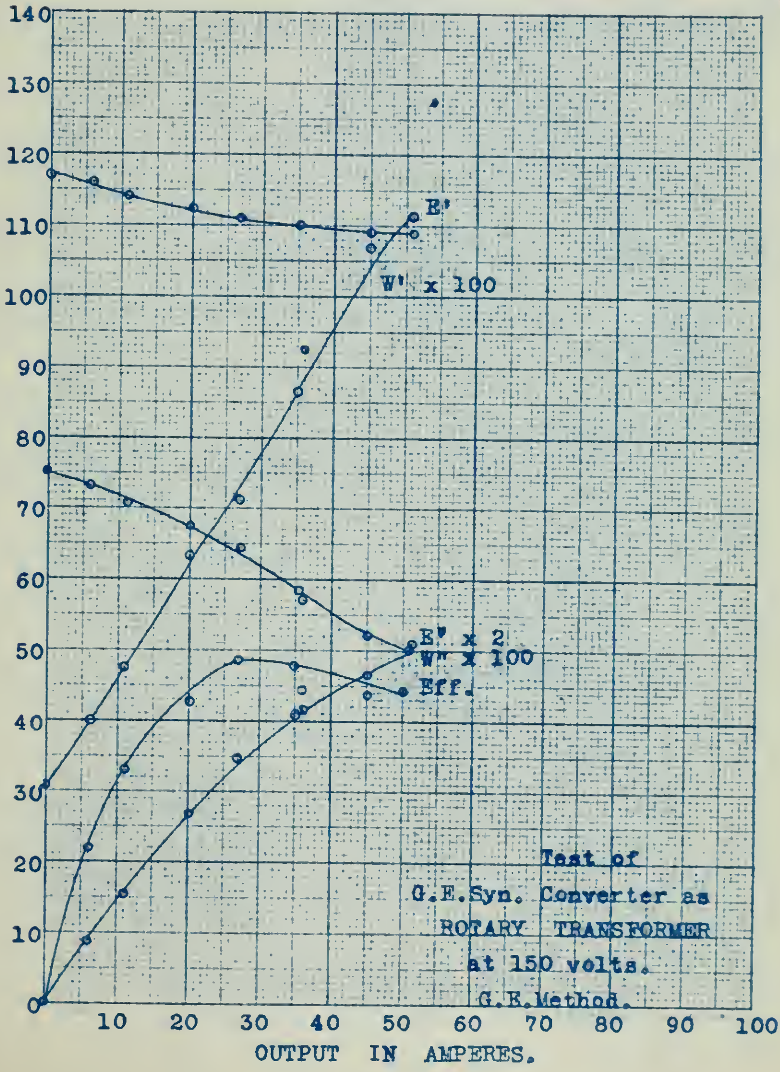
E_1	E_2	I_1	I_2	W_1	W_2	Eff%	Speed
118.0	114	20.1	0	2170	0	0	
114	109	24.4	5	2555	545	21.4	
114	107	29.4	10	3352	1070	32.0	
114	104	35.4	15	4041	1560	38.7	
112	102	40.3	20	4515	2040	45.2	
113	100	46.4	26	5125	2600	50.7	
111	96	51.3	30	5700	2880	50.5	
111	94	56.3	35	6251	3290	52.5	
111	91	62.3	40	6923	3640	52.6	
110	88	68.2	45	7550	3957	52.4	
110	84	74.2	50	7922	4200	53.0	
110	81	82.2	55	9022	4451	49.4	
109	78	86.2	60	9448	4680	49.6	
109	73	93.2	65	10160	4745	40.8	
109	69	99.2	70	10918	4823	44.0	
108	66	103.1	77	11221	5180	46.1	


140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
10
20
30
40
50
60
70
80
90
100
OUTPUT IN AMPERES.
W' x 100
E'
E"
W" x 100
Eff.
Test of
G.E.Syn. Converter as
ROTARY TRANSFORMER
at 114 volts

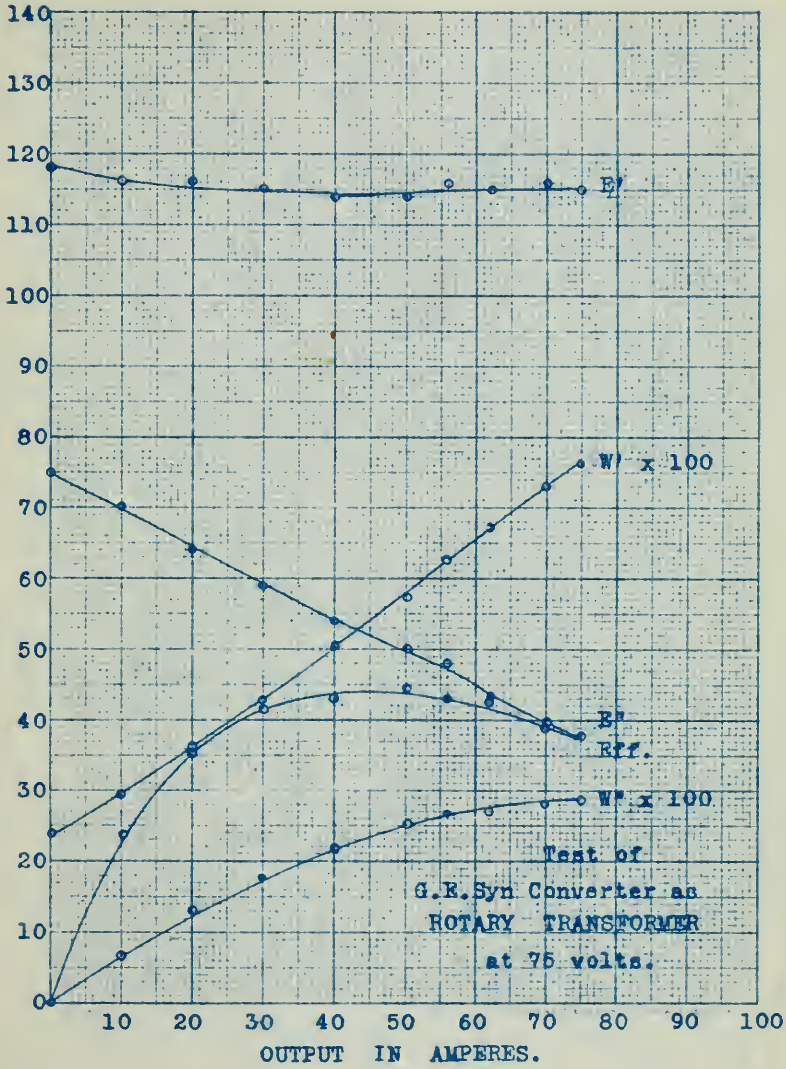
ROTARY TRANSFORMER

G.E.Syn. Converter. G.E.Method.

E_1	E_2	I_1	I_2	W_1	W_2	Eff%	Speed
117	150	26.4	0	3087	0	0	
116	146	34.4	6	3991	876	21.9	
114	141	41.3	11	4710	1551	33.0	
112	135	56.2	20	6300	2700	42.9	
111	129	64.2	27	7120	3481	48.8	
110	117	78.2	35	8610	4098	47.6	
110	114	84.2	36	9270	4110	44.3	
109	104	98.0	45	10685	4683	43.8	
109	100	102.0	51	11110	5100	45.9	
118	75	20.5	0	2420	0	0	
116	70	25.4	10	2956	700	23.7	
116	64	31.4	20	3640	1280	35.2	
115	59	37.3	30	4285	1770	41.4	
114	54	44.3	40	5052	2180	43.2	
114	50	50.3	50	5740	2500	44.4	
115	51	50.3	50	5790	2550	44.1	
116	448	54.3	56	6290	2690	42.8	
115	43	58.5	62	6710	2685	42.5	
116	40	62.8	70	7290	2800	38.4	
115	38	66.2	75	7610	2850	37.4	



Test of
G.E.Syn. Converter as
ROTARY TRANSFORMER
at 150 volts.
G.E.Method.

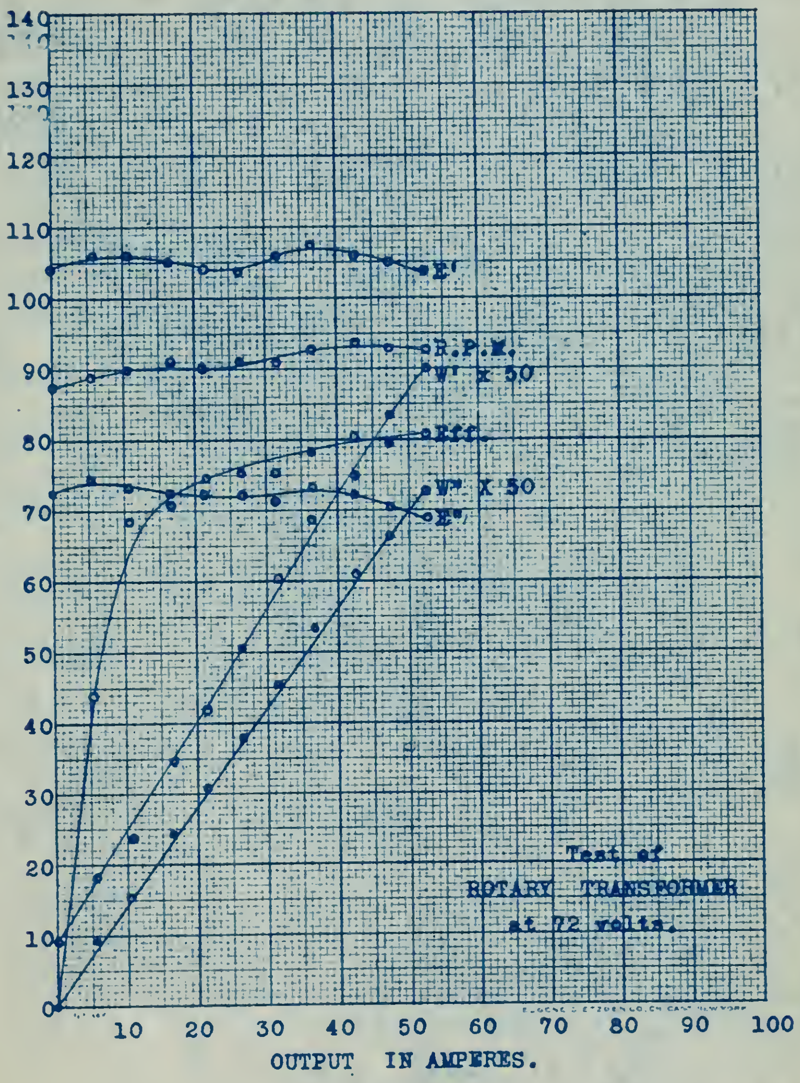


Test of
G.E.Syn Converter as
ROTARY TRANSFORMER
at 75 volts.

ROTARY TRANSFORMER

Multiple. Full Comp. English Method.

E_1	E_2	I_1	I_2	W_1	W_2	Eff%	Speed
104.0	72.8	4.4	0	457	0	0	874
106.0	74.2	8.7	5.6	922	415	43.8	890
106.0	73.5	11.3	10.6	1198	779	68.4	900
105.0	72.5	16.4	16.8	1723	1218	70.6	910
104.0	72.0	20.2	21.1	2100	1518	72.2	900
104.0	72.2	24.2	26.4	2530	1905	75.4	910
106.0	71.2	28.4	31.7	3012	2254	75.2	910
107.5	73.2	31.9	36.8	3430	2690	78.5	929
106.0	72.0	35.6	42.4	3772	3050	80.8	938
105.0	70.4	39.7	47.1	4170	3318	79.6	929
104.0	69.0	43.3	52.5	4502	3620	80.4	929


140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
10
20
30
40
50
60
70
80
90
100
OUTPUT IN AMPERES.
E'
R.P.M.
W' x 50
Eff.
W" x 50
E"
Test of
ROTARY TRANSFORMER
at 72 volts.

were taken from the generator brushes through the compound winding to a junction point forming short circuited brushes. The load was connected between this junction point and one side of the line by means of a double pole switch. Ammeters were placed in the shunt field, supply line, each leg of the short circuited brushes, and in the load line. The potential of the supply and load was recorded. The object of the ammeters in series with the short circuited brushes was to give the current circulating through the generator brushes but not accounted for in the load circuit.

When operating the machine at no load, the ammeters in the short circuited brush circuits showed no current. However, when the load was thrown on the circulating current reached a value of ten per cent of the output. This was caused by a difference of potential between short circuited brushes, due to the shifting of the commutating plane with respect to the brush position. This resulted in severe heating of the compounding turns. More sparking occured at one brush than at the other, excessive heating of the armature and commutator resulted. This connection showed a marked increase in speed regulation.

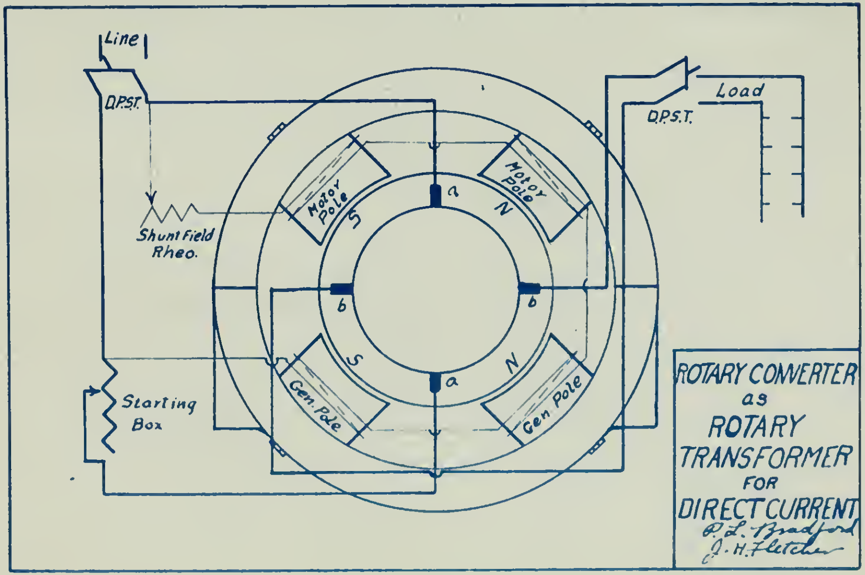
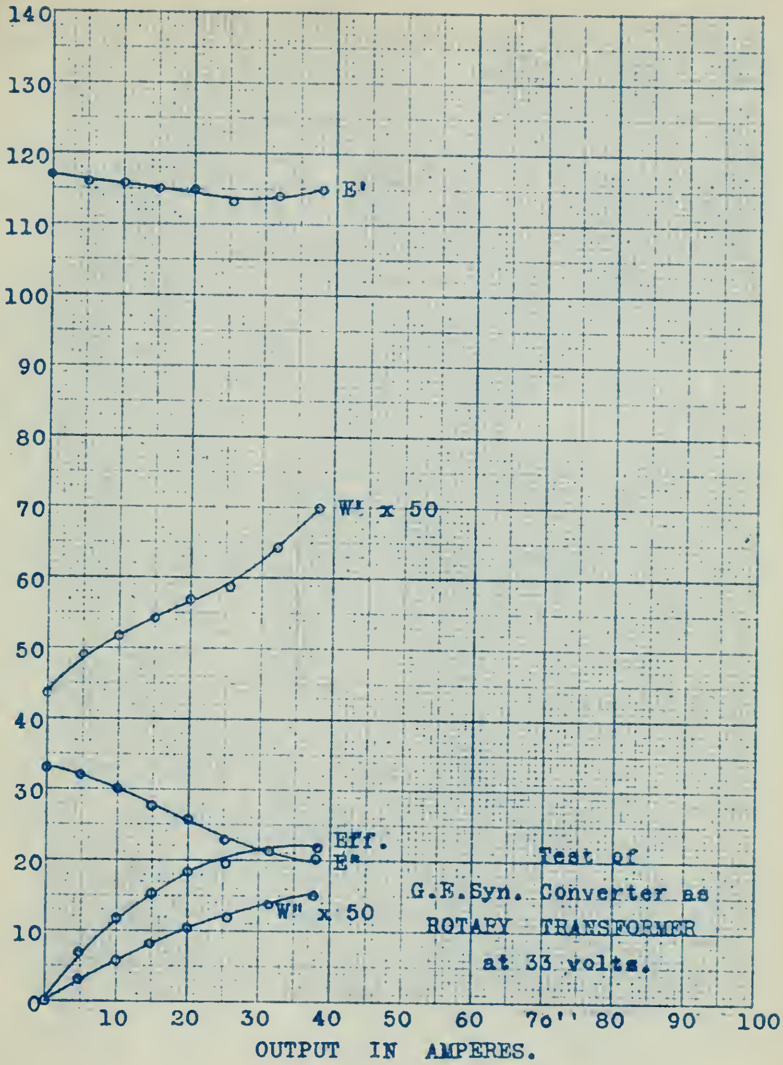

Line
D.P.S.T.
Shunt Field
Rheo.
Motor Pole
Motor Pole
S
N
a
b
b
S
N
a
Gen. Pole
Gen. Pole
Starting
Box
D.P.S.T.
Load
ROTARY CONVERTER
as
ROTARY
TRANSFORMER
FOR
DIRECT CURRENT
P. L. Bradford
J. H. Fletcher

Fig. 3.

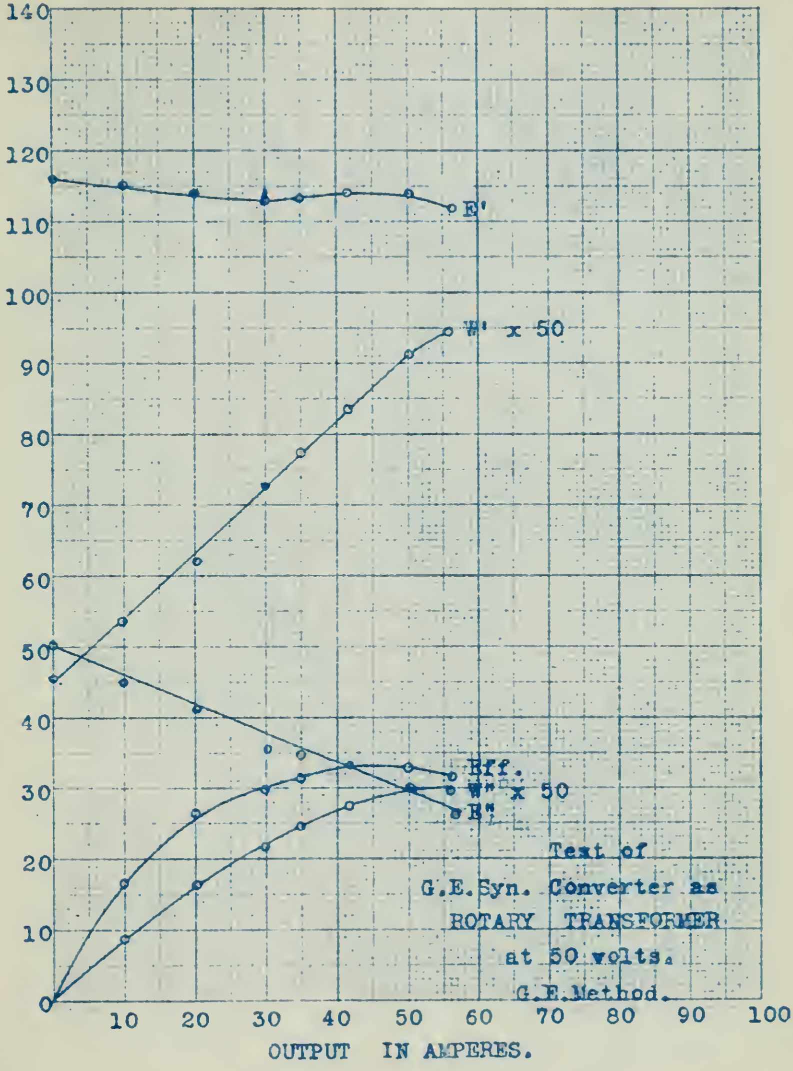
ROTARY TRANSFORMER

G.E.Syn. Converter. G.E.Method.

E_1	E_2	I_1	I_2	W_1	W_2	Eff %	Speed
116	50.0	19.5	0	2261	0	0	
115	45.0	23.3	10.0	2680	450	16.8	
114	41.0	27.2	20.0	3100	820	26.4	
113	36.0	32.2	30.0	3640	1080	29.5	
113	34.5	34.2	35.0	3862	1209	31.2	
114	33.5	36.8	41.5	4190	1389	33.2	
114	30.0	40.3	50.0	4580	1500	32.8	
112	26.5	42.1	56.0	4720	1481	31.4	
117	33.0	19.3	0	2260	0	0	
116	32.0	21.2	5.0	2460	160	6.5	
116	30.0	22.2	10.0	2578	300	11.6	
115	27.5	23.7	15.0	2722	412	15.1	
115	26.0	24.7	20.0	2840	520	18.3	
113	23.0	26.1	25.4	2942	575	19.5	
114	21.5	28.2	32.0	3216	679	21.1	
115	20.0	30.2	38.0	3498	760	21.7	



Test of
G.E.Syn. Converter as
ROTARY TRANSFORMER
at 33 volts.

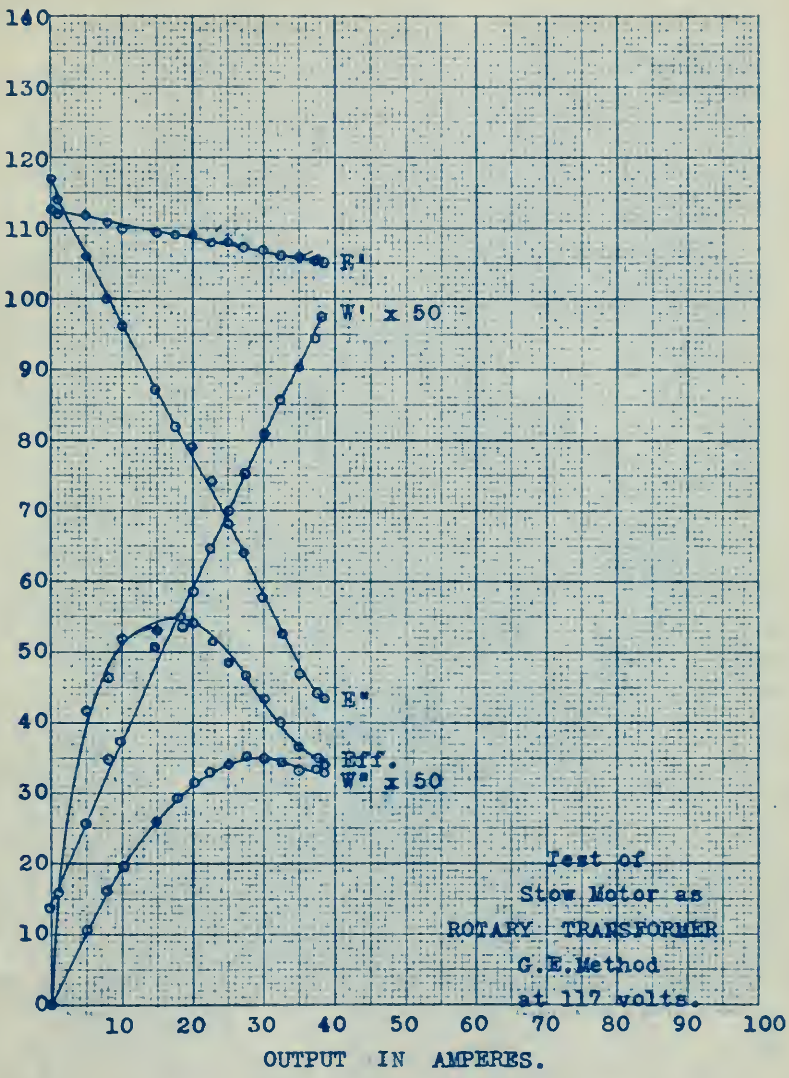


Test of
G.E. Syn. Converter as
ROTARY TRANSFORMER
at 50 volts.
G.E. Method.

ROTARY TRANSFORMER

Stow Motor. General Electric Method.

E_1	E_2	I_1	I_2	W_1	W_2	Eff%	Speed
112.5	117.0	6.0	0	676	0	0	
112.0	116.	6.3	0.5	706	58	8.2	
112.0	114	7.2	1.0	805	114	14.2	
112.0	106	11.5	5.0	1285	530	41.6	
111.0	100	15.7	8.0	1740	800	46.0	
110.0	96	16.9	10.0	1865	960	51.5	
109.5	87.2	23.0	15.0	2524	1306	53.0	
109.0	82.0	25.3	18.0	2760	1475	53.5	
109.0	79.0	26.9	20.0	2937	1580	54.0	
108.0	74.0	29.9	22.5	3232	1665	51.6	
108.0	68.0	32.4	25.0	3500	1700	48.5	
107.5	64.0	35.0	27.5	3760	1760	46.8	
107.0	58.0	37.8	30.0	4055	1740	43.0	
106.0	52.5	40.3	32.5	4280	1705	40.0	
106.0	47.0	42.6	35.0	4522	1640	36.4	
105.0	44.0	44.8	37.5	4710	1650	35.0	
105.0	43.5	46.2	38.5	4860	1673	34.4	


140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
10
20
30
40
50
60
70
80
90
100
OUTPUT IN AMPERES.
E'
W' x 50
E"
Eff.
W" x 50
Test of
Stow Motor as
ROTARY TRANSFORMER
G.E.Method
at 117 volts.

It was possible to obtain an efficiency of fifty-two per cent. The greatest marked advantage of this method over the previous one was voltage regulation, of 1.2 per cent for a range of current from zero to fifty amperes. The difficulties met with in this machine were due to its lap wound armature and the interaction of field flux due to the continuous yoke.

The foregoing preliminary work demonstrated that if we were to obtain a machine consisting of one rotating member and one commutator capable of raising or lowering the supply voltage any pre-determined amount and operate successfully it must have, a ring wound armature, in order that the two halves of the conductor shall not be subjected to different flux densities at the same instant and that there must be two complete and magnetically isolated field circuits, in order to prevent the interchange of flux.

Having determined the mechanical requirements of such a machine, we decided that the most satisfactory method of proceedure would be to use two Crocker-Wheeler bipolar motors. Due to the peculiar construction of this type of motor, it was possible to mount two similar

machines about one rotating member, by cutting down the length of the field poles.

The Electric Laboratory was equipped with one such machine, rated at four horse power, and mounted on a #3 frame. A second bipolar Crocker-Wheeler motor with a #3 frame was secured. New field poles of proper length were designed and cast of mild steel. In order to magnetically insolate the generator field from the motor field, the iron bearing pedestals of one machine were replaced by brass, designed especially for that purpose. These also serve to support one magnetic circuit above the other, The new field poles were bored to correct curvature; due to the peculiar construction of the machine it was necessary to bore the halves independent.

Upon examination, we found that it was necessary to reconstruct the field coils. These were found to be of #22 and #23 B. & S. gauge, double cotton covered wire, respectively for the two machines used. By test these coils were found to be of different resistances. For the #22 B. & S. coils, 56.1 ohms each; for #23 B. & S. coils, 94.0 ohms each. It was deemed necessary to reduce these coils to the same number of turns.

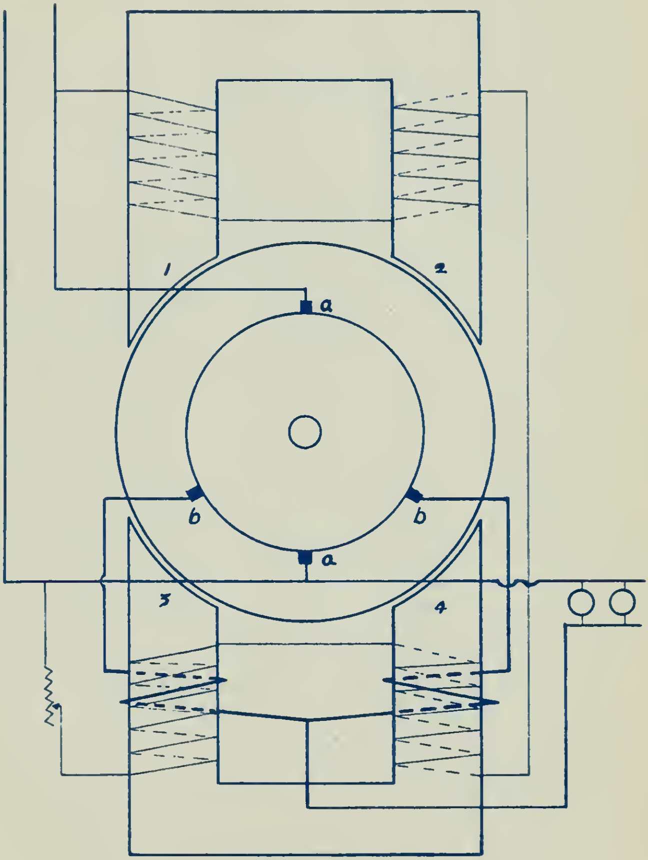


Fig. 4.

This was accomplished as follows:

The mean length of one turn #22 B. & S. was found to be 1.506 feet; for #23 B. & S., 1.376 feet per turn. From the B. & S. tables the resistance per 1000 feet of #22 wire is 15.9 ohms at 20° Centigrade, for #23 wire the resistance is 19.93 ohms per 1000 feet at 20° Centigrade. Therefore, the total length of #22 B. & S. per coil was 3530 feet, and for #23 B. & S. per coil, was 4880 feet. The turns of wire per coil of #22 B. & S. were 2340; for #23 B. & S. were 3420. Therefore, it required 1080 turns per coil of #23 B. & S. wire to be removed in order that all coils should have the same number of turns. After correcting these coils, a test of the two coils of #23 B. & S., in series, showed 140 ohms resistence. For the two coils of #22 B. & S. in series, the resistence was 129 ohms.

In figuring for the flux, the inside diameters of the coils were for #22 B. & S., 4.25 inches; for #23 B. & S. 3.75 inches; giving effected areas of 14.18 and 11.05 square inches respectively. For the coils of #22 wire the effective flux was

$$Z = 48 \times 14 = 672 \text{ turns.}$$

This corresponds to fourteen turns per section, and forty-eight sections on the armature.

If E = Volts,

n = Speed in revolutions per second

p = Number of poles.

p_1 = Number of paths in parallel

ϕ = Number of lines.

Then

$$\phi = \frac{E_a p_1 \times 10^8}{pZn}$$

$$\phi = \frac{110 \times 2 \times 10^8}{2 \times 672 \times 15}$$

$$\phi = 1{,}090{,}000 \text{ lines.}$$

$$\beta = \frac{\phi}{A} = 77{,}000 \text{ lines.}$$

For coils of #23 B. & S. wire.

$$\phi = \frac{110 \times 2 \times 10^8}{2 \times 672 \times 17.5}$$

$$\phi = 937{,}000 \text{ lines.}$$

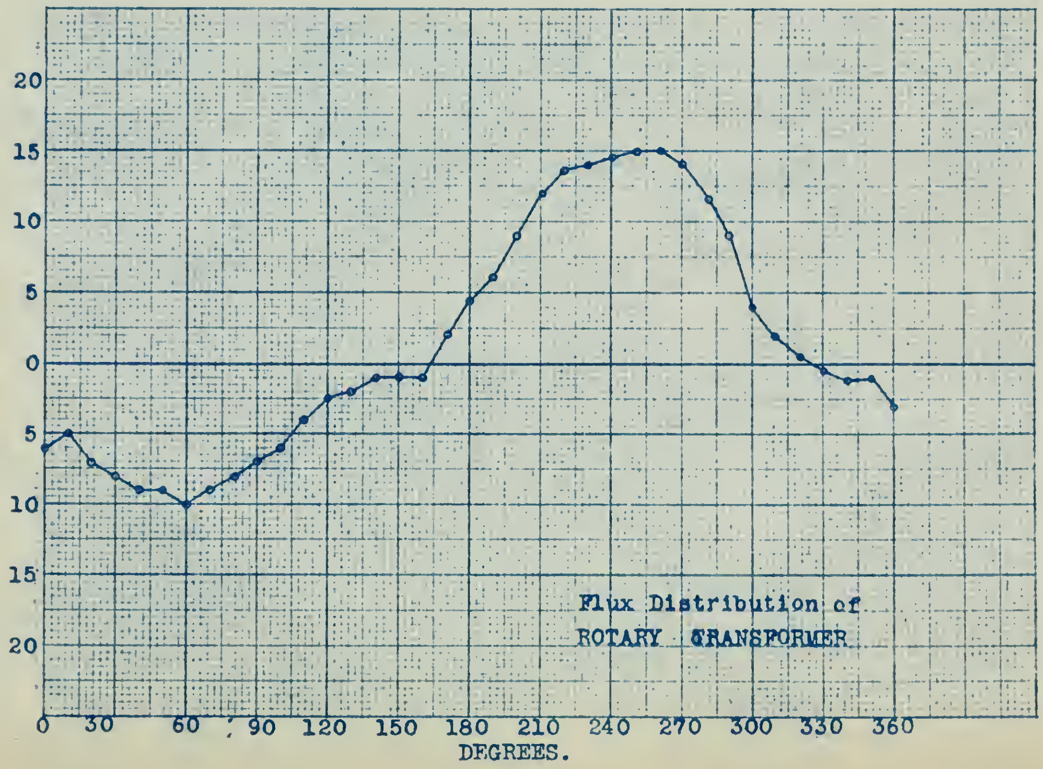
$$\beta = 84{,}900 \text{ lines.}$$

In figuring the compounding to be placed on the motor field, the current density was taken at one thousand circular mills per ampere. This requires a wire of 25,000

circular mils, corresponding to a diameter of .158 inches. A #8 B. & S. wire having a bare diameter of .1280 inches was chosen, with a double cotton cover, its diameter is .142 inches. The number of turns per layer per pole is equal to the space across the coil divided by the diameter of the wire, In this case, 3.5 inches divided by .142 inches which equals approximately twanty-four turns. Eight layers, giving 196 turns were used. These were placed 98 turns per pole. With a mean length of nineteen inches per turn it required 310 feet or 15.5 pounds of #8 B. & S. wire. The resistence of these coils was .093 ohms, and .093 ohms respectively. Taps were brought out from the central portion of the compounding, the resistence of this portion was .0413 and .0413 ohms respectively.

The shunt coils were connected so that the generator and motor fields were multipled across the supply circuit. They were placed in multiple to increase the current through each coil, which resulted in an increase of flux per pole, and a reduction of speed. The brush gear consisted of a rigid rocker arm, carrying the motor brushes (a, a). The generator brushes were carried on independent rockers, whose relative position could be changed at will.

The line current was delivered to the motor brushes (a, a) which were placed in the virtical plane as shown in Fig. 4. The generator brushes,(B., b), were short circuited through the compound winding on poles 3 and 4. Poles 3 and 4 being generator poles for step down and motor poles for step up transformations. The load was connected between the junction point of the short circuited brushes and one side of the supply circuit. Under normal conditions, when there is no circulating current flowing through the armature across the short circuited brushes, each brush and each main coil will be carrying half the secondary load current; if, however, a circulating current arises, it will flow in opposition to the load current in one coil 3, and in conjunction with a load in the other coil, 4; in effect, therefore, the current in coil 3, will be less than in 4, and if these coils are suitably coupled up, will have the effect of correcting or preventing the short circuited current from rising to any considerable value. In other words, as the current in coil 3 is less than the current in coil 4, the m.m.f.. of pole 3 is less than the m.m.f. of 4, and this tends to cause a greater voltage to be generated under pole 4, than under pole 3, thus opposing the voltage which is creating the

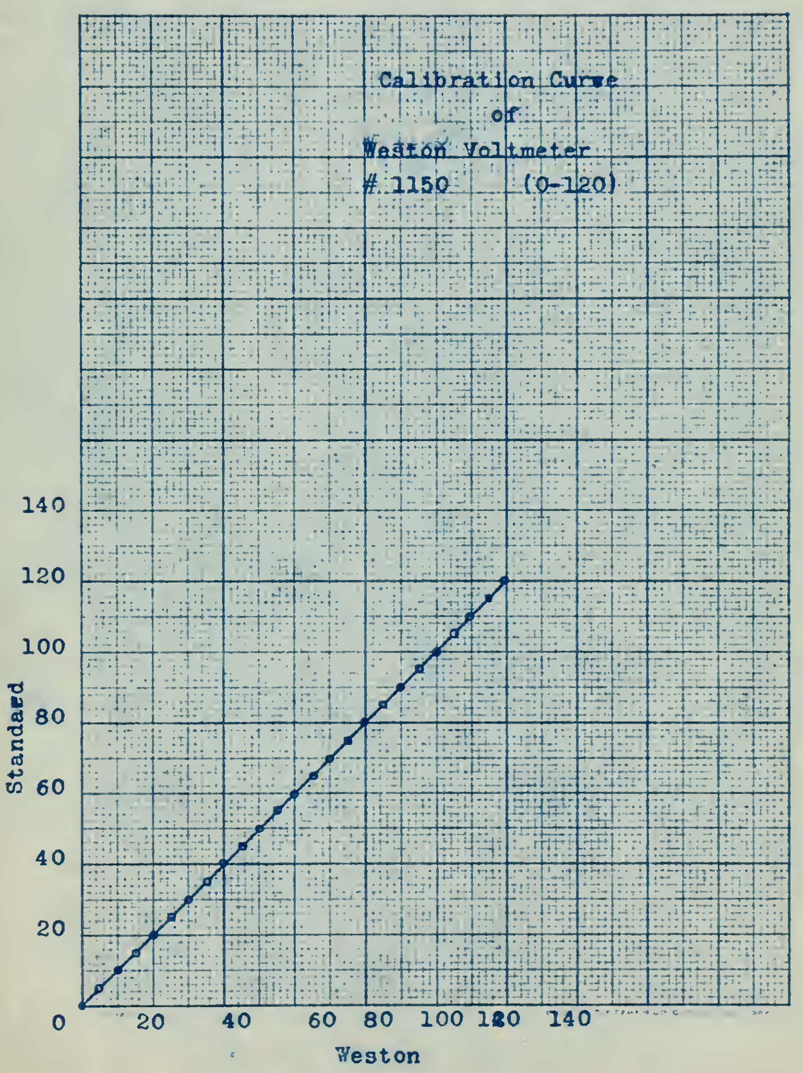


Flux Distribution of
ROTARY TRANSFORMER

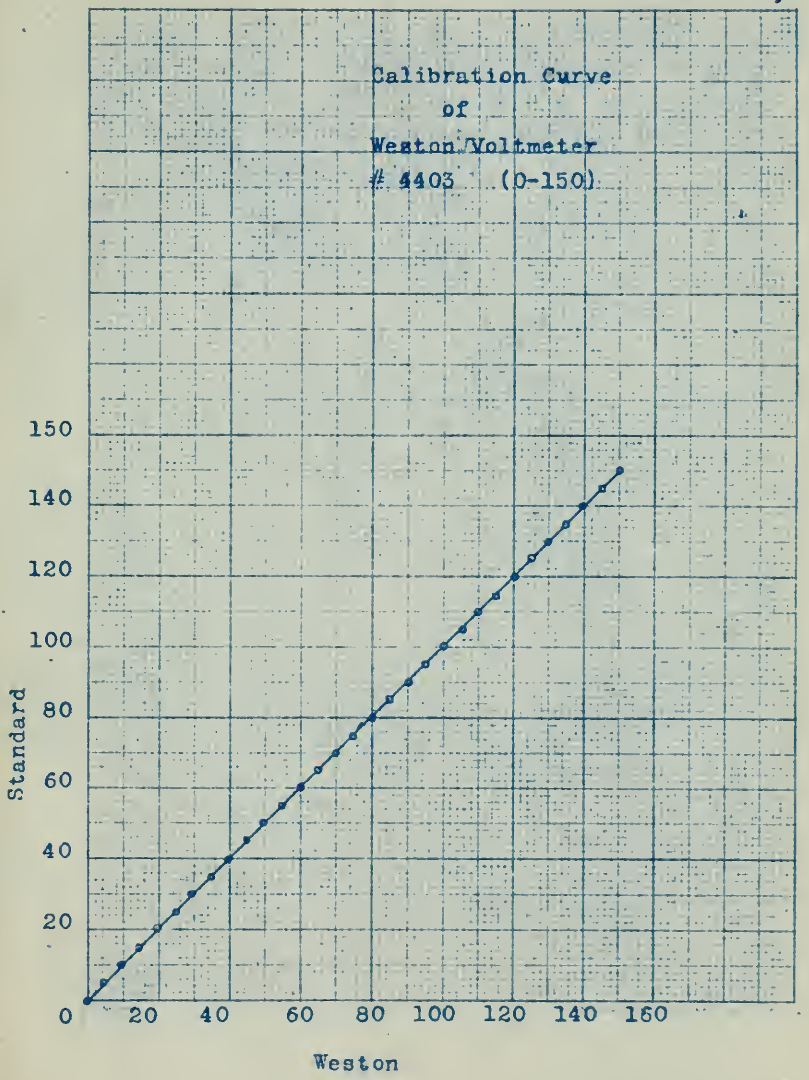
circulating current.

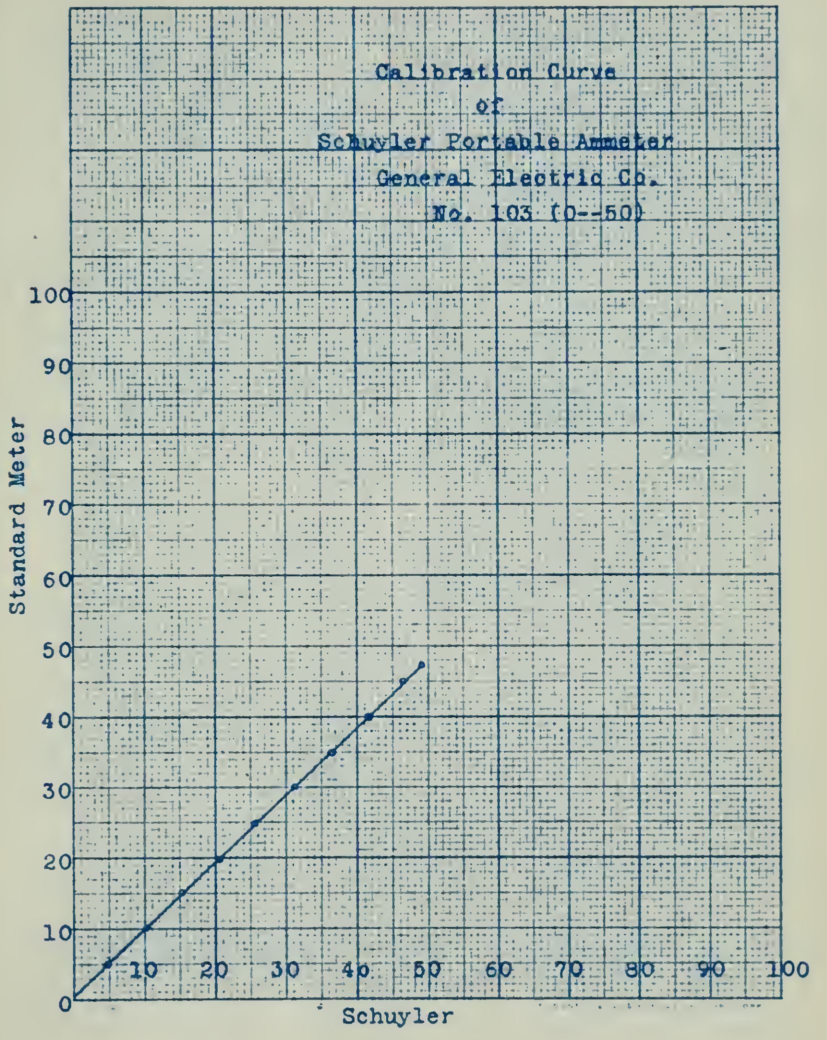
In connecting this machine, ammeters were placed in the field circuit, line circuit, and load circuit. Voltmeters were connected across the supply and secondary terminals, an alternating current voltmeter was connected across the brushes (b, b) to give the difference of potential between them, which was responsible for the short circuited current. A magneto and voltmeter was calibrated to give the speed. The magneto being belt-driven from the armature shaft. For starting a carbon pile rheostat was inserted in the supply line. This was parallelled by a short circuiting switch which was closed when the machine was up to speed. Suitable protective apparatus was installed in the line. The load was taken up by carbon piles on low voltage, and lamp racks in series on high. All instruments were calibrated before and after the test. Curves for these are included in this report.

Runs were taken for both full and half compounding at potentials varying from thirty-three to eighty volts on the secondary side, and for full compounding

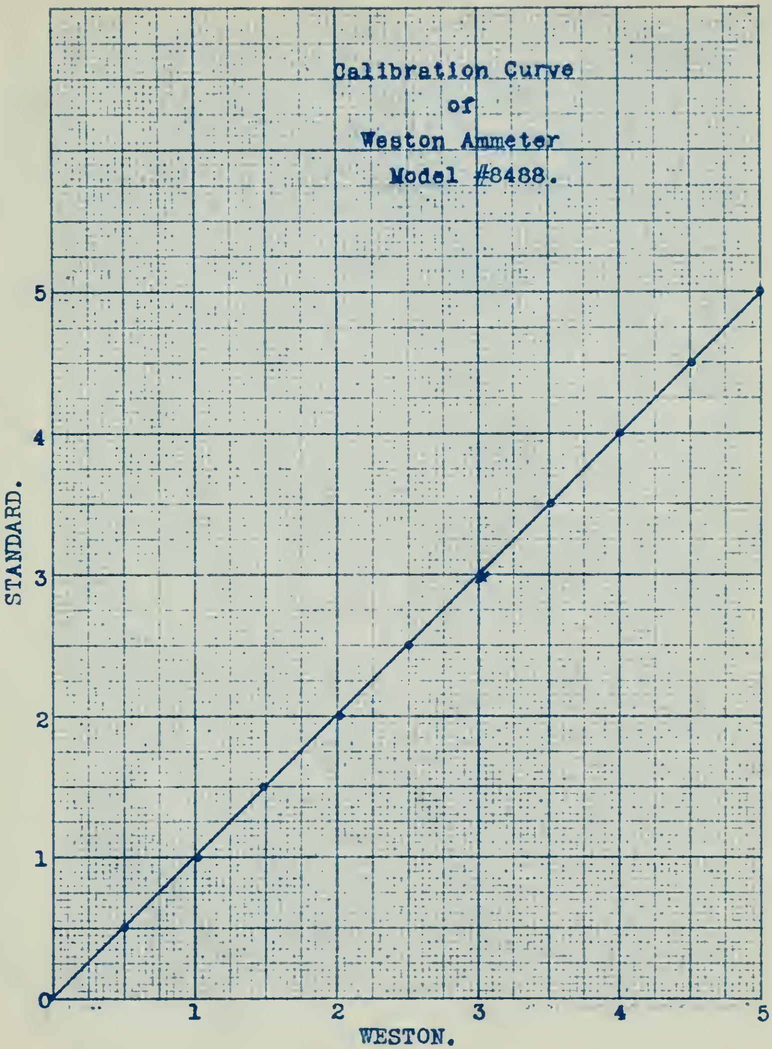


Calibration Curve
of
Weston Voltmeter
1150 (0-120)

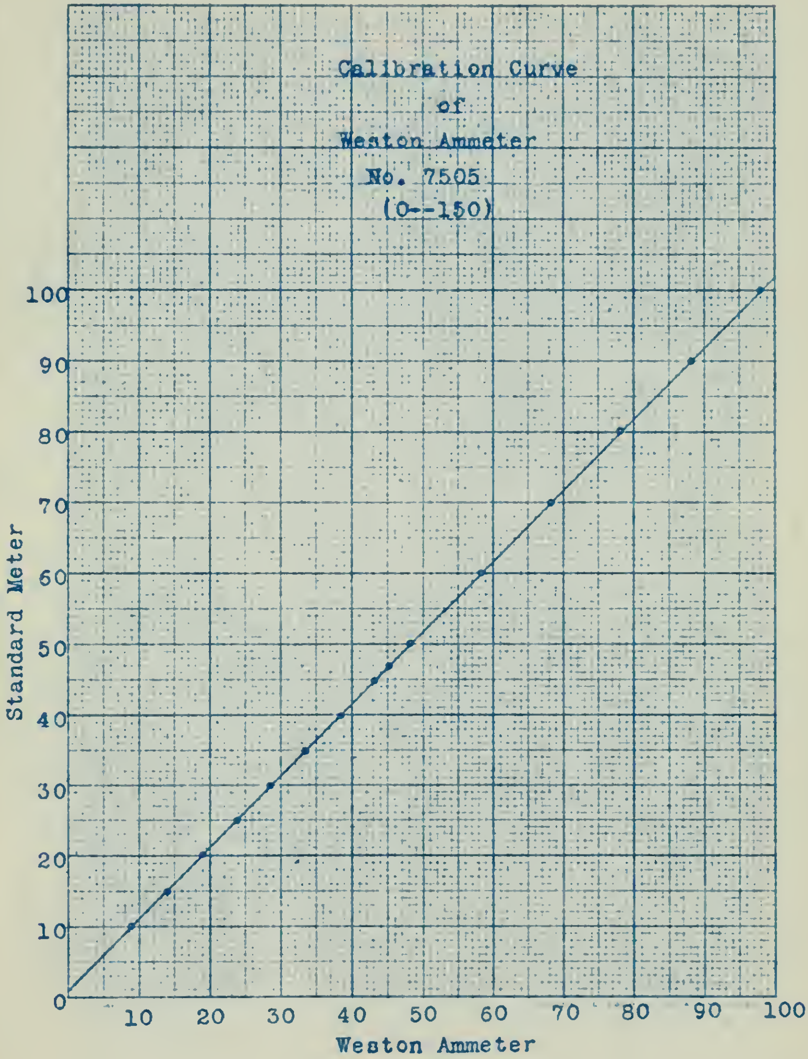

Calibration Curve
of
Weston Voltmeter
# 4403 (0-150)
150
140
120
100
80
60
40
20
0
Standard
20
40
60
80
100
120
140
160
Weston

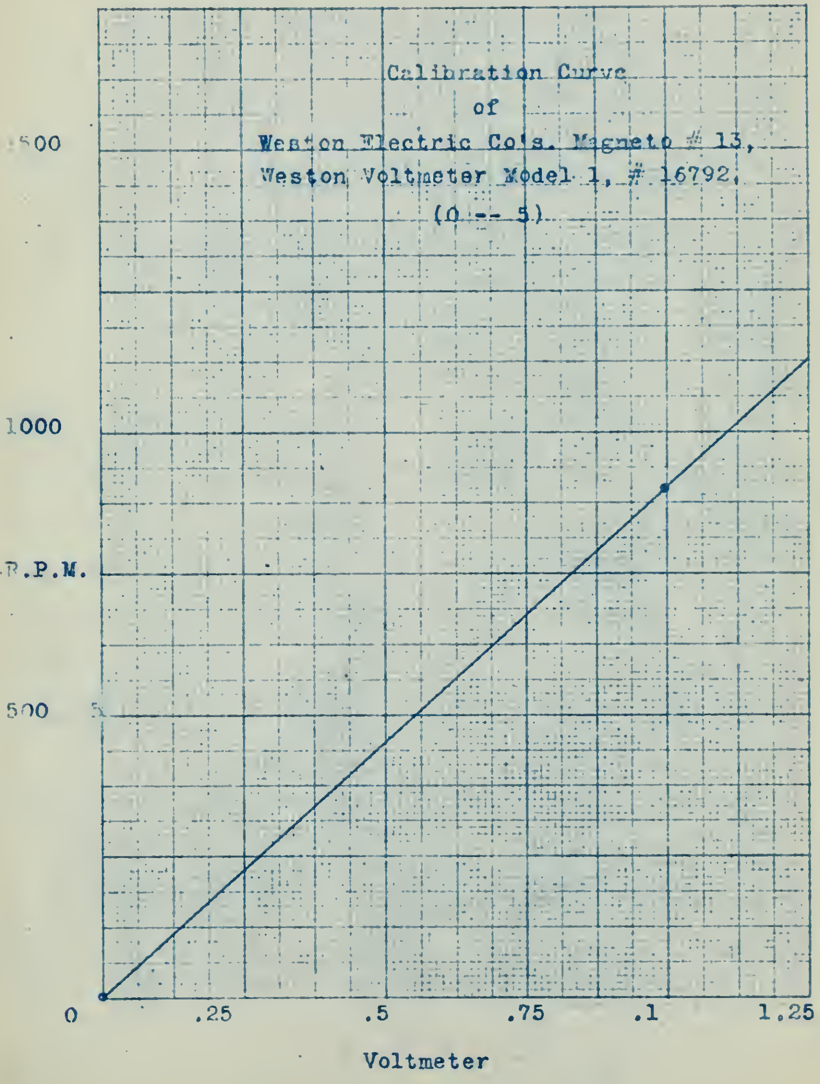


Calibration Curve
of
Schuyler Portable Ammeter
General Electric Co.
No. 103 (0--50)
Standard Meter
100
90
80
70
60
50
40
30
20
10
0
10
20
30
40
50
60
70
80
90
100
Schuyler



Calibration Curve
of
Weston Ammeter
Model #8488.


Calibration Curve
of
Weston Ammeter
No. 7505
(0--150)
Standard Meter
Weston Ammeter
0
10
20
30
40
50
60
70
80
90
100



Calibration Curve
of
Weston Electric Co's. Magneto # 13,
Weston Voltmeter Model 1, # 16792,
(0 -- 5)

from 142 to 220 volts on the secondary side. When running the machine as a step up transformer the fields were supplied from the generator side in order to keep down the speed.

Several preliminary runs were necessary and considerable adjusting was required to eliminate the pounding due to magnetic drag. This consisted in readjusting the air-gaps, which also resulted in eliminating the sparking at all brushes. During the preliminary runs, when the machine reached about forty per cent full load, pounding began, but this decreased as full load was applied. This was found to be due to the air-gap on one of the generator poles being too small,which caused the armature to be dragged towards that pole,as the effect of the compounding increased, this was counteracted,by the flux of the compounding acting against the flux of the shunt winding and also as the flux of the opposite generator pole increased, it drew the armature toward it . The commutator was slightly rough, causing a chattering of the brushes. After several applications of sand-paper, the greater part of the uneven-

ness was eliminated. It was thought advisable not to turn the commutator down on account of a small diameter.

Throughout the final runs the rotary transformer showed nearly constant speed for all loads when fully compounded, when using the half-compounding taps, there was an appreciable increase in speed, in some instances amounting to fifteen per cent. The results taken from the enclosed data are tabulated, for one-half and full load, as follows.

Full Compounding E_2	Half Compounding E_2	Half Load Eff.	Full Load Eff.
33		49.1	57.7
35		61.3	71.8
	35	60.0	68.0
40		61.9	72.9
45		66.6	76.8
55		68.2	76.4
70		75.4	80.5
	70	71.7	79.6
72		70.6	80.8
80		74.6	84.0

This data shows that in each case the half load efficiency is relatively very high; also that the efficiency increases as the secondary potential increases. The effect of compounding is to increase the efficiency in each case. The voltage regulation is much improved by the use of the full compounding.

A summary of the results for the rotary transformer used to step up are given below.

Full Compounding E_2	Half Load Eff.	Full Load Eff.
142	69.2	78.0
150	72.8	79.4
175	57.7	72.3
210	50.0	59.6
220	47.6	51.3

The limited range of load obtained on this machine due to its small capacity and high voltage, give a very limited working range. But the results obtained demonstrated that it is entirely possible to use this machine for stepping up the vol-

tage. Throughout the runs the initial speed was much increased over the speed of the machine when used as a step down transformer, but did not show an appreciable increase during the range of the load. This may be accounted for by the relatively small portion of the flux being active in generating a counter e.m.f. in the motor portion of the armature. The voltage regulation is but a small perccentage. Sparking increase with the increase of speed due to poor commutation.

A second method of connection was attempted. This consisted in connecting the two generator terminals to the load at what was previously a short circuiting point. This was practically operating the machine as a separate motor and generator, The result was a rapid decrease in generator voltage with an increase in load. Sparking occured at low loads and the speed decreased rapidly.

A heat run of eight hours was taken; during the first two the machine was operated at an over load to heat the windings, during the remaining six hours it was loaded normally. All readings remained practical-

ly constant. The temperature increased twenty and a half degrees Centigrade by the thermometer method, and twenty-six and a half degrees Centigrade by the change of resistence method. Throughout the runs there was sparkless commutation, even running and no apparent strain put upon the machine at any time.

For the several methods of wiring the machine to run as a rotary transformer for direct current work, but one was of commercial value. The test of the Stow motor and Rotary Convertor demonstrated the impractibility of attempting to run a machine composed of a solid magnetic yoke, due to the interaction of magnetic fields, which eliminates the voltage regulation. Or, the use of any type of armature, except the ring wound, due to the cutting of unequal numbers of lines of force by opposite sides of the same conductors, which is equivalent to an open circuited coil at two positions in the field.

Further, it was found entirely satisfactory to employ a machine of two magnetically insolated yokes, and a ring wound armature. First, because either the generator or motor field could be changed without re-

gard of the other, thus giving a means of controlling the speed and voltage regulation. The ring-wound armature was found to work satisfactorily, due to the fact that but one side of the conductor cuts the field flux at any time, and consequently has no tendency to set up opposing voltages in the inductor. It was found possible to place a series winding on the generator field, which automatically controlled the voltage at all loads.

This type of machine was found to give an efficiency which surpasses the motor-generator sets or dynamotors. It requires less floor space, has fewer parts, and costs less. It can be used for any purpose that either of the above mentioned machines are practical, beside having the characteristic of operating on short circuits with but a slight increase over normal current.